SOME ASPECTS OF FISHERY BIOLOGY OF *Puntius sophore* (HAM.)

THESIS

SUBMITTED FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

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Dedicated

To

My Brother

University of Allahabad

Department of Zoology

Certificate

This is to certify that the thesis entitled ***"Some aspects of fishery biology of Puntius sophore (Ham.)"*** embodies the original work conducted by Ms. Rajshree Srivastava in the Department of Zoology, University of Allahabad during January 2001 to April 2003. Ms. Rajshree has put in the required attendance as per rules of the University .

This is further certified that Ms. Rajshree has successfully completed her Pre – D. Phil. / Pre – submission seminar on 26th April 2003 in the Department of Zoology, University of Allahabad and is hereby allowed to submit her thesis for the award of D. Phil. degree in Zoology.

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CHAPTER I

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Fish can be defined as poikilothermic aquatic vertebrates which breathe by means of gills, move with the help of fins, and are primarily dependent on water as a medium in which they live. Fishes constitute a well defined and highly successful taxonomic group of vertebrates and constitute almost half of the total number of vertebrates. Out of 39,900 vertebrate species recognised the world over 21,723 are extant species of fishes of which 8411 are of freshwater and 11650 marine species. In the Indian region alone, 2500 fish species are reported, out of which 930 are freshwater inhabitants and 1570 are marine (Jayaram, 1999)

Fish are natural renewable resource, not only in terms of biodiversity but as a source of high quality animal protein food for the people. Among animals, fishes have been considered as one of the most important creatures and exploited since the dawn of human civilization. Fishery resources of freshwater, marine and other water bodies are used as food and for manufacturing other by-products. During last few decades, advances in aquaculture technologies have helped to raise fish production so called 'blue revolution' has played a commendeble role not only in providing protein rich food but also in poverty alleviation in our country.

During recent years attempts have been made for the development and conservation of inland fishery resources (Ghosh, 2001) which include rivers (45,000 kms), canals and creaks (1,26,334 km), reservoirs (30,20,000 ha), floodplain lakes (2,10,000 ha), estuaries (27, 00,000 ha), coldwater upland lakes (72,000 ha), lagoons

(190,000 ha) and ponds and tanks (22,50,500 ha). Fish production in the country registered an impressive growth of eight times during the last 50 years. From 0.75 million t in 1950-51, annual fish production has reached 5.6 million t during 1999-2000 of which fish production is 2.9 million t and inland fish production 2.7 million t (Sugunan,2001). Now efforts are also being made for sustainable development of fisheries based on the application of scientific management forms and unproved technologies.

Among the major river systems of India, the Ganga river system is considered most important. It has a total length of about 8,047 km. Fishery resources of the Ganga river system have been studied by a number of workers (Hamilton - Buchnan, 1922; Jhingran, 1970; Menon, 1974; Singh *et al.,* 1998; Khan, 2000 and Payne et al.,2003). It is known to harbor 265 fish species, out of which the major carps and some larger catfish form the backbone of fishery. This river system is the original habitat of the most prized carp species, *viz., Catla catla, Cirrhinus mrigala, Labeo rohita, Labeo calbasu,* which are the key species for Indian aquaculture. Besides these it comprises other minor carps, catfishes and other miscellaneous fishes.

In the Ganga river system, the present trends of fisheries may be attributed to the impact of changes in the riverine environment. Of all the factors responsible for creating riverine environmental changes, water pollution is considered the most important. The contamination of water with a variety of domestic, agricultural and industrial wastes has been reported (Bilgrami *et al.,*1992). The effect of water pollution may be briefly described as physical effects (changes in turbidity), oxidation effects producing an increased BOD and oxygen deficit in water, toxic chemical effects caused by a range of substances that cause immediate or cumulative physiological changes in biotic

organisms, chemical nutrient effects caused by excessive amounts of nitrogen, phosphorus and pathogenic effects caused by microorganisms. A number of other factors such as changing land use pattern and resulting changes in or loss of riparian vegetation have also contributed to the changes in riverine environment. Such changes not only modify the environment, depriving the fish of living space and access to parts of the river necessary for the completion of their life cycles, but also bring about changes in the quality and the quantity of water in which they live (Bilgrami and Dattamunshi, 1985). Changes caused by fishing pressure including selective capture fishing and other anthropogenic effects also adversely effect the fisheries. The present status survey of riverine fisheries and analysis of fish catch composition revealed that the trends of fisheries are quiet different from those recorded earlier (Singh *et al.*, 1998).

The knowledge of fishery biology is quiet essential for proper management, conservation and judicious exploitation of fishery resource. These studies include the racial analysis of the fish population, their length-weight relationship, food and feeding habits, fecundity and spawning biology, age and growth, and various other aspects of population dynamics. Therefore, it is no wonder that fishery biology of a large number of commercially important fish species has been studied by fishery scientists in different parts of the world.

In India, many workers have studied the fishery biology of different fish species including *M. dobula* (Kesteven, 1942), *Clupisoma garua* and *Eutropiichthys vacha* (Motwani and Karamchandani, 1958), *Mystus seenghala* (Saigal and Motwani, 1961), *Pangasius pangasius* (David, 1963), *Catla catla* (Natrajan and Jhingran, 1963), *Rita rita* (Lal, 1970), *Mystus seenghala* (Bhatt, 1970), *Rita rita* (Saxena, 1972), *Tor putitora* (Das

and Pathani,1978), *Schizothorax richardsonii* (Mishra, 1982), *Tor putitora* (Nautiyal, 1982), *Crossocheilus latius latius* (Pokhriyal, 1986), *Wallago attu* (Anwar and Siddiqui, 1989), *Clupisoma garua* (Afser, 1991), *Pseudotropius atherinoides* (Panigrahi *et al.*, 1991), *Glptothorax madraspatanum* (Dobriyal and Singh, 1993), *Crossocheilus latius latius* (Negi, 1998), *Labeo calbasu* (Singh, 1999), *Clupisoma garua* (Pandey, 2001) and *Priacanthus hamrur* (Sivakami et al., 2001).

A review of literature shows that no work has been done on the fishery biology of *Puntius sophore*. Hence the present work was conducted during 2001-2003. Some important aspects of fishery biology studied by me are : morphometrics, length-weight relationship, food and feeding habits, breeding biology and age and growth.

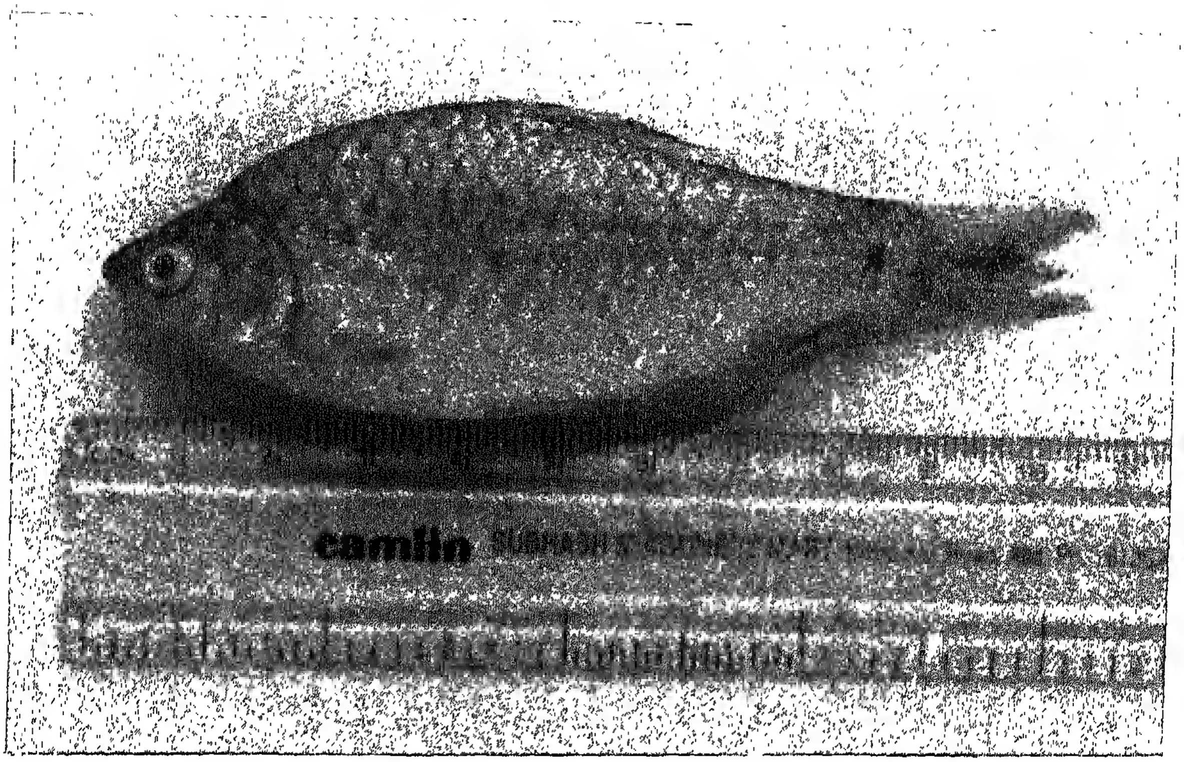


Fig. 1

CHAPTER II

MATERIALS AND METHODS

Material and Methods

The study was conducted on *Puntius sophore* (Hamilton) (Fig 1). The classification of this fish is as follows :

Classification

Class	:	Teleostei
Sub class	:	Actinoptrygii
Order	:	Cypriniformes
Division	:	Cyprini
Sub order	:	Cyprinoidei
Family	:	Cyprinidae
Sub family	:	Cyprinini
Genus	:	*Puntius*
species	:	*sophore*
Local name	:	Putia
Fin formula	:	D.11(3/8); P.15-16; V.9;A.8 (3/5);C.19;L.1.25-26; L tr.5-5½ /5-5½

Fish samples of *Puntius sophore* were obtained from the Ganga river system at Allahabad to study the following aspects.

1. Morphometrics

Specimens of *P. sophore* were collected from the Ganga river system during the period of January 2001 to December 2002. In all 631 specimens of varying lengths formed the material for the present study. The morphometric measurements were taken to the nearest

millimeter. Eleven morphometric characters were considered for this purpose. These are Total length (TL), Standard length (SL), Head length (HL), Snout length (SntL), Eye diameter (ED), Postorbital length (POL), Predorsal length (PDL), Prepelvic length (PPL),Preanal length (PAL), Maximum body depth (MBD) and Caudal length (CL). The morphometric measurements have been defined on the basis of description provided by Jayaram (1981) and Srivastava (1998), which are as follows :

Total length (TL) : From the tip of the snout to the tip of caudal fin.

Standard length (SL) : From the tip of the snout to the base of caudal fin.

Head length (HL) : From the tip of the snout to the posteriormost bony extremity of the opercle.

Snout length (SntL) : From the tip of the premaxillary emphasis to the anterior margin of eye.

Eye diameter (ED) : From margin to margin of the bony orbit.

Postorbital length (POL) : From the posterior margin of the orbit to the posterior most edge of the opercular bone.

Predorsal length (PDL) : From the tip of the snout to the origin of the dorsal fin.

Prepelvic length (PPL) : From the tip of the snout to the origin of the pelvic fin.

Preanal length (PAL) : From the tip of the snout to the origin of the anal fin.

Maximum body depth (MBD) : Maximum distance between the dorsal and ventral profile of the body.

Caudal length (CL) : From the base of the caudal fin to the tip of the caudal fin.

Regression analysis

Regression analysis was conducted for each relationship between independent and dependent variables. The regression equation and the coefficient of regression for all the relationships were determined by using the straight line equation,

$$Y = a + b X$$

where, Y = dependent variable

X = independent variable

a = intercept

b = slope

Correlation coefficient (r) was calculated for each relationship to show the significance of the results. The linearity of regression was tested by analysis of variance (ANOVA). The significance of correlation coefficient (r) was tested by Student's t- test with the help of the following formula,

$$t = \frac{r \sqrt{n - 2}}{\sqrt{1 - r^2}}$$

2. *Length- weight relationship*

A total of 616 specimens, 212 males (44-93 mm) and 404 females (44-116 mm) were used for the present study. The freshly caught specimens, after removing the moisture were measured for recording the length and weight of each fish. The lengths of fish were measured to the nearest millimeter from the tip of the snout to the end of caudal fin and weight was measured to the nearest gram. The data was processed on computer for logarithmic transformation and regression analysis.

The length - weight relationship was estimated by the method of least squares using the parabolic equation as suggested by LeCren (1951),

$$W = aL^b$$

Through the logarithmic transformation, this relationship was expressed as :

$$Log\ W = Log\ a + b\ Log\ L$$

where, W = weight of fish

L = length of fish

a = a constant

b = regression coefficient

Values of a and b were calculated empirically by the method of least squares. The parabolic relationship was expressed by plotting the numerical values of length and weight and logarithmic relationship was expressed by plotting the calculated log weight against log length. The correlation or linearity of regression has been tested by analysis of variance (ANOVA; 'F' test).

Based on the data collected and computed for length-weight relationship, relative condition factor was calculated and represented graphically. The relative condition factor 'Kn' was estimated by using the formula :

$$Kn = \frac{W}{w}$$

where, Kn = Relative condition factor

W = Observed weight

w = Calculated weight

3. *Food and feeding habits*

For anlysing the food and feeding habits of *Puntius sophore*, fishes were collected every week. After recording their length and weight, they were dissected and the entire guts were taken out, uncoiled and cleaned of attached tissues. After recording the length, guts were preserved in 5% formalin and detailed analysis of food contents was conducted by both qualitative and quantitative.

Quantitative analysis

A number of methods have been employed by various investigators for the analysis of gut contents in fishes. Job (1940) followed thé volumetric method. Bapat and Bal (1950) estimated the percentage of various food items of some inshore fishes by eye assessment. The stomach content of freshwater sticklebacks was studied by Hynes (1950) by adopting the point method. Bhimachar and George (1952) combined both point method and number method. Pillay (1952) suggested that the methods to be adopted depends entirely on the feeding habit of fish. The point method with certain modification was employed by Ventatraman (1960). Natrajan and Jhingran (1962) proposed the method 'index of preponderance' for the analysis of stomach content, which was adopted by James (1967) for ribbon fishes and found suitable for carnivorous fishes.

In the present study because the presence of diatoms, small algae and parts of plant material in the food contents of *Puntius sophore* the above methods could not be applied for the quantitative analysis. Therefore, in the present case for evaluating the different food items, The point method of Swynnerton and Worthington (1940), as reviewed and modifies by Hynes (1950) and Pillay (1952), was adopted. *Puntius sophore*, being a typical cyprinid fish has no conventional stomach and its place is taken

by a swelling at the anterior part of the intestine, which is called the Intestinal Bulb (IB). Therefore, the whole alimentary canal was selected for the analysis of different food items present in it. Weight of gut contents were determined by weighing it with and without contents. The contents of each gut were preserved in 5% formalin of known volume. The food items were identified under a microscope. Since the items of food were smaller in size, their volume could be estimated only by allotment of points. To find out the percentage composition of different food items; the food was diluted in a known volume and from it 1 ml was transferred into the Sedgwick Rafter slide. For calculating the percentage of each food item 'Point method' was adopted.

Point Method

The average feeding intensity was evaluated by point method. The points were assigned depending on the fullness of gut as 20, 15, 10, 5 and 0 for full, 3/4 full, 1/2 full, 1/4 full and empty guts respectively. The fish was considered as an active feeder when gut was full and 3/4 full, moderate when 1/2 full and poor when 1/4 full or with empty guts. The points were allotted to the state of gut on the basis of general idea about the quality of the food taken by the fish. The individual food item and its percentage was calculated by the use of Sedgwick Rafter counting slide.

Feeding intensity

The degree of feeding is called feeding intensity and was ascertained by the examining the fullness of guts and by Gastrosomatic index.

Gastrosomatic index (GaSI)

The gastrosomatic index was calculated by using the following formula :

$$GaSI = \frac{\text{Weight of gut contents}}{\text{Weight of fish}} \times 100$$

Feeding Index (FI)

The feeding index was calculated to express the feeding intensity by recording the number of full and 3/4 full guts and then their total percentage was calculated for each month.

Relative length of gut (RLG)

The RLG for each fish was determined by the formula :

$$RLG = \frac{\textit{Total length of the gut}}{\textit{Total length of the fish}}$$

Qualitative analysis

Different food items were identified by microscopic examination. Qualitative analysis of different food items upto generic level were made with the help of freshwater Biology by Needham and Needham (1962) and Ward and Whipple (1959).

4. Breeding biology

Fishes for the present study were collected round the year and brought to the laboratory in fresh condition. Various body measurements were taken before cutting open the abdomen. Due to the absence of any sexual dimorphism an abdominal incision was made to know the sex for the separation of male and female fish. Gonads were removed and preserved in Aquous Bouin's fluid and allowed to harden for several days. Prior to determination of various stages of maturity and homogeneity of ova diameter was assessed in few ovaries.. For this purpose sub-samples from the anterior, middle and posterior parts of the ovary were examined individually under the microscope. Sincethe

distribution of ova was found non-homogeneous, a fixed number of 100 ova from anterior, middle and posterior part of each ovary was randomly measured with the help of an ocular micrometer as Omd (ocular micrometer division).

Macroscopic examination were also made to support the microscopic results. The frequency of spawning and spawning season was studied by tabulation of percentage occurrence of fish in various stages of maturity month wise and size wise and also by the ova diameter frequency polygons. The different maturity stages were determined according to the ICES (Wood, 1930). For determining the size at first maturity the data collected during spawning season was considered for this examination. The regression line so calculated from the regression equation by the method of least squares using the formula Y = a + b X, fitted the data well and the 50% level in the maturity has been taken to represent the mean length at which maturity was obtained.

The Gonadosomatic index (GSI) was also calculated for each fish by using the following formula :

$$GSI = \frac{\textit{Weight of gonad}}{\textit{Weight of fish}} \times 100$$

A total of 63 mature females of *Puntius sophore* were taken for the estimation of fecundity. Fish length, fish weight, ovary length and ovary weight values were recorded. The fecundity was estimated by gravimetric method (Simpson, 1959)in which three sub - samples from the anterior, middle and posterior parts of the ovary taken and their weight was recorded separately. The number of ova in each sample was counted under the binocular microscope and fecundity was estimated as follows :

$$Fecundity\ (F) = \frac{S \times OW}{WOS}$$

Where, F = Fecundity

S = Average number of ova obtained from the samples of the ovary

OW = Average weight of ovary

WOS = Average weight of the subsamples of the ovary

Various relationships of body parameters with fecundity were obtained by using the method of least squares *i.e.*

$$Log\ Y = Log\ a + b\ log\ X$$

Where, X = independent variable *i.e.* body parameters

Y = independent variable *i.e.* fecundity

a = intercept

b = slope

The number of fish samples in each month were segregated on the basis of their sex (male / female) The homogeneity in the distribution of males and females of *Puntius sophore* was estimated by computing the percentage of males and females for each month and the and the significance of sex ratio was tested by Chi - square analysis by using the following formula,

$$\text{Chi – square } (X^2) = \sum \frac{(O - E^2)}{E}$$

Where, O = observed value

E = expected value

5. Age and growth

The scales were used for the study of ageing biology of *Puntius sophore*. For this study "Key scales", *i.e.*, below the dorsal fin and above the lateral line were sampled. The

scales were washed in water, then placed in 1% KOH solution for 5-10 minutes and again washed with water. The scales were pressed within blotting paper while drying in order to avoid their curling. Finally, the cleaned scales were kept in ordinary envelops containing the morphometric data of each fish (Lagler, 1977).

Prior to age determination, the establishment of the fact is important that the annual increment in scale radius maintains a constant ratio with the increment in fish length throughout the year. For the purpose the scale radius from focus to lateral margin were measured with the help of microfilm reader commonly known as "Dokumator". Fish length- scale radius relationship was traced out with the help of standard regression analysis,

$$Y = a + bX$$

Where X = Fish length, an independent variable

Y = Scale radius, a dependent variable

a and b = constants

Now the scales were subjected for further examination which includes the identification of "annuli" and its measurements from focus. Also the minimum width in terminal zone (i.e., the distance from the last annuli to margin) was noticed in each scale, each month round the year. The data was further analysed to find out the month and probable cause of annuli formation.

To understand the detailed structure of different parts of scale, SEM (Scanning Electron Microscopy) studies were carried out. For SEM studies, the scales which were earlier used for age determination were cleaned with distilled water and subjected to sonication with mild acetone, so as to remove the mucus, organic particles, dust and other

extraneous matter from the scale. These scales were subjected to scanning electron microscopy. The cleaned and air dried scales were mounted on the metal stubs. These stubs are either made up of aluminium or brass. The scales were placed on the stubs with dorsal surface upwards and the ventral surface sticking on the double adhesive tape. Care was taken to avoid the trapping of air bubbles under the tape. As scales are non-conductive specimens these were coated with a thin layer (100 A) of gold in a gold coating unit so as to overcome the problem of "charging" and "beam damage". An additional advantage of coating is an improvement in the strength of the secondary electron signals, coating with gold increased the yield of secondary electrons. The gold coating was done in a sputter coating unit. The scale samples were viewed under vacuum in the JEOL JSM-6100 scanning electron microscope, at an accelerating voltage of 20 KV at low probe current and photographed.

Based on the scale reading following formulae have been used for various growth parameters.

Back calculation

The growth rate of fish was calculated by Back - calculation method as suggested by Fraser (1916) after including correction factor to the formula suggested by Lea (1910), which is based on the fact that the scales are formed when fish has already attained some length.

The formulae are as follows :

$$ln - a = \frac{Sn}{S} (l - a)$$

Where, ln = length of fish when annulus n was formed

l = length of fish when scale sample was obtained

Sn = length of scale radius to annulus 'n'

a = correction factor

Growth parameters :

Following growth parameters were calculated as suggested by Tandon and Johal (199

(i) *Specific rate of linear growth*

$$C_l = \frac{ln - ln_{-1}}{ln_{-1}} \times 100$$ (Chugunova, 1963)

(ii) *Specific rate of weight increase*

$$Cw \text{ or } Cg = \frac{Wn - Wn_{-1}}{Wn_{-1}} \times 100$$ (Chugunova, 1963)

(iii) *Index of population weight growth intensity*

$$\Phi Cw = \frac{\sum_{Cw=1}^{n_j + a} Cw}{n_j + a}$$ (Balon, 1971 a)

(iv) *Index of species average size*

$$\Phi h = \frac{\sum_{h=1}^{n_j + a} h}{n_j + a}$$ (Balon, 1971 a)

(v) *Growth characteristic*

$$C_{th} = \frac{\log ln - \log ln_{-1}}{0.4343} \; ln_{-1}$$ (Vasnecov, 1934- Quoted from Holick and Hensel, 1971)

(vi) Growth constant

$$C_{lt} = \frac{\log l_n - \log l_{n-1}}{0.4343} \quad \frac{t_2 + t_1}{2} \qquad \text{(Chugunova, 1963)}$$

Where

l_n and l_{n-1} are mean computed total length of fish at ultimate and penultimate years of life.

W_n and W_{n-1} are mean computed weights at ultimate and penultimate years of life

j = juveniles

a = adults

n = number

h = absolute increase in length

l = length

weight

t_2 and t_1 are time intervels between ultimate and penultimate age classes and the value of $\frac{t_2 + t_1}{2}$ is equal to 1.5.

Harvestable size

The minimum theoretical harvestable size has been determined from the crossing point obtained by plotting the length increment (h) as percentage of the length of first growth season and average length at each age class as percentage of the length of the final growth season, against the corresponding age classes in the same graph (Balon, 1971)

Age at first maturity

It was determined for male and female separately by plotting size at first maturity with the average fish length at the time of annulus formation.

Length frequency distribution method (Petersen's method)

This method is based on the assumption that the young ones of a fish population have a single season i.e. breeding season for the completion of a year. When the monthly data of round the year plotted on the basis of size groups and percentage occurrence (frequency), clumping of fish of successive ages around successive given lengths will occur. The graphically obtained modes were indicative of age groups.

CHAPTER III

MORPHOMETRICS

MORPHOMETRICS

INTRODUCTION

Morphometric characters are useful for the identification of fish species. These characters are helpful for detecting minor variations within a species and form an important basis in the taxonomy for the recognition of sub-species. It reflects the proportionate growth of different body parts and the influence of environmental factors in a particular habitat. Variation in form, from one population to another is usually analysed in terms of counts (meristic characters) and measurements (morphometric chracters). Morphometry is also useful in detecting intraspecific variations among fishes which may be due to ecological or genetic differences and provide rational basis for the management and exploitation of fisheries. Based on these characters the fishes can be easily identified and distinguished from each other.

For the fishes of India, Pakistan, Ceylon and Burma, Day (1878, 1889) produced a monumental monograph on the basis of analysis of morphometric characters and described the ratio of different body parts with the total length of fish.

Mishra (1962) reviewed the fishes of India. Menon (1974) listed the fishes of Himalayan and Indo-Gangetic plains. Jayaram (1981) described the taxonomy of freshwater fishes of India, Pakistan, Bangladesh, Burma and SriLanka. Dattamunshi and Srivastava (1988) and Talwar and Jhingran (1991) described the morphometric and taxonomic chracters of fishes. Srivastava (1998) gave a detailed account of morphometry and taxonomy of fishes of U. P. and Bihar.

Besides these, various attempts have been made in India and abroad to describe the morphometric and taxonomic characters of fishes by various workers including Chu,(1935); Shaw and Shebbeare (1937), Hora and Nair (1940), Hora (1941), Pillay (1952, 1954 a,b, 1957 a,b), Sarojini (1953, 1957, 1958), Schaefer (1955), Mishra (1959), Tandon (1962), Banerjee and Venkateshwarlu (1968), Lal and Dwivedi (1969), Seshappa (1970), Banerjee (1973), Chondar (1974, 1976), Lal and Mishra (1980), Natrajan *et al.*,(1977), Blatz and Moyle (1981), Srivastava and Pandey (1981), Mishra (1982), Nautiyal (1982), Seth *et al.*,(1983), Singh and Dobriyal (1983), Al-Absey and Ajiad (1988), Pokhriyal and Singh (1992), Tandon *et al.*,(1993), Johal *et al.*,(1994), Samad and Jafri (1994), Pandey *et al.*,(1995), Pandey and Nautiyal (1997), Bhatt *et al.*,(1998 a,b), Singh and Singh (2000), Pandey (2001), Gulathi and Acharya (2001), Dutt and Kumar (2001), Cakic *et al.*,(2002).

The present chapter deals with the study of morphometric characters and their mathematical relationships in *Puntius sophore* (Ham.) procured from the Ganga river system at Allahabad.

OBSERVATIONS

Puntius sophore (Ham.) (Fig. 1), a common freshwater teleost is locally known as 'Putia'. Body is relatively deep, its dorsal profile more convex than ventral. The colour of the body is beautiful silvery, black-grey green to brownish, flanks with a somewhat bluish lusture, underside white. Mouth is terminal and barbels absent. There are two black blotches one at the base of caudal fin and the other at the base of third to fifth branched dorsal rays. Caudal fin forked and homocercal.

A comparative account of the data pertaining to eleven morphometric measurements is given in Table 1.1. During the present investigation the maximum total length was observed up to 116 mm. Various morphometric parameters were statistically analysed in the ratio and percentage of each dependent variables in relation to total length, standard length and head length presented in Tables 1.2 and 1.3 respectively. In the present study, it was observed that all the morphometric parameters *viz.* Standard length (SL), Head length (HL), Snout length (SntL), Eye diameter (ED), Postorbital length (POL), Predorsal length (PDL), Prepelvic length (PPL),Preanal length (PAL), Maximum body depth (MBD) and Caudal length (CL) show a positive relationship with total length of fish. The maximum body depth (average 21.8±4.4) was more than that of the head length (average 16.9±2.7). The average ratio values being 3.25 in total length, 2.64 in standard length for maximum body depth and 4.14 in total length and 3.408 in standard length for head length. The dorsal, ventral and anal fin originated at an average distance from 29.4 mm, 30.9 mm and 45.0 mm respectively from the tip of the snout. The eye diameter (2.96 in ratio and 33.31 in percentage of head length) was greater than snout length (4.28 in ratio and 23.302 in percentage of head length). The average length of caudal fin (15.1 mm) was smaller than that of head length (16.9 mm); the average ratio of caudal fin (5.71 in TL and 5.41 in SL) and head length 4.14 in TL and 3.408 in SL) also revealed that the caudal fin was slightly smaller than that of latter. Among three morphometric measurements in ratio of head length the snout length, eye diameter and postorbital length have the values of 4.28, 2.96 and 2.29 respectively. In the present study the ratio of dependent variables *viz.*, standard length , head length, snout length , eye diameter, postorbital length, predorsal length, prepelvic length, preanal length, maximum

body depth and caudal length was observed in increasing order, whereas the percentage in decreasing order in relation to total length of fish. The same situation exists in snout length, eye diameter and postorbital length in relation to independent variable, head length.

Regression analysis of body measurements and their relationship

The regression analysis of various body parameters are computed from the data of Table 1.1. The relationship for various body measurements, determined by fitting the straight line equation, revealed that the dependent variables (Standard length, Head length, Snout length , Eye diameter , Postorbital length , Predorsal length, Prepelvic length, Preanal length, Maximum body depth and Caudal length) were highly correlated with the corresponding independent variable (total length, standard length, head length) which implied that the former increased simultaneously with the increase of latter. The regression equations for various relationships. correlation coefficient (r) and t-test are shown in table 1.4. Higher values of correlation coefficient (r) were recorded for all the measurements in relation to total, standard and head length ranged from 0.8088 to 0.9937. The values of correlation coefficient (r) was tested by applying t-test and it was found that all the values are significant at 1% level. The linearity of regression between independent and dependent variables were proved by analysis of variance (ANOVA) presented in Table 1.5.

DISCUSSION

The analysis of morphometric characters involves the study of meristic (count of fin rays, number of lateral line scales, scutes, pharyngeal teeth, gill rakers and vertebrae) and non-meristic characters (measurements of various body parts in relation to total or standard

length of fish). These characters play a important role in the identification of fish species and sub-species. Morphometrics is a convenient technique for segregating the fish population. Morphometric data have been employed in systematics in the study of races or population and somewhat more recently in the study of various body parts The term population refers to a group of individuals of the same species occupying a definite niche. Different populations of a species usually exhibit differences in certain morphometric and meristic characters. According to Howard (1954), the differences in structure may arise as a result of changes in the local environment or through genetic variations which result from natural selection during long period of geographical isolation.

Issen *et al.*,(1981) were of the view that morphological characters including morphometric measurements, meristic counts, shape and size provide data that are useful for precise description of and differentiation among stocks. Lindsey (1961) considered these characters to be a convenient technique for segregating fish population. Pivnicka (1970), Pivnicka and Hensel (1978), Libosvarsky and Ruben (1985) and Issen *et al.*, (1981) employed morphometric characters extensively for the separation of sub-species from different ecological and geographical regions. Various workers in India and abroad conducted their studies on morphometric characters in order to ascertain homogeniety or heterogeniety in various populations of the species inhabiting the same or different water bodies.

Jones (1954) while working on the hilsa population of the Hooghly, Mahanadi and Chilka lake ascertained fish species as a homogeneous population. Pillay (1954) stated that *Mugil tade* collected from different places belong to a homogeneous population. Later on Pillay (1954a, 1957a, 1957b) and Pillay *et al.*(1962) observed that

the samples of *Hilsa ilisha* collected from river Hooghly, Mahanadi and Chilka lake belong to a separate stock. This was in contradiction to the earlier observation made by Jones (1954)on *Hilsa ilisha*. He separated the Hilsa population of Chilka lake from the rivers Hooghly and Mahanadi.

Sarojini (1957) made a racial study of the *Mugil persia* samples collected from the fore shore area of the sea at Jaunput Diamond Harbour and Post canning and came to the conclusion that population of this species from these areas were derived from a homogeneous population. Tandon (1962)concluded that the *Selaroides leptolepis* collected during 1957 - 59 from different centers probably do not indicate the existence of distinct population. David (1963) established that population of *Pangasius pangasius* from the rivers Godavari and Krishna in South India are entirely different and require distinct status of sub-species. During the present investigation it was observed that the samples collected from Ganga river system belong to homogeneous stock.

Studies on similar lines have been made by Rao (1965) and Jogelkar and Rao (1967). Rao (1965) studied the morphometric characters of *S. insularis insularis* and *S. insularis baweanensis* and distinguished these two sub-species from each other. He further conducted comparative studies on the morphometric characters of *S. insularis insularis* from Walfair, Godavari and Pamban estuary and observed significant differences among them.

Lal and Dwivedi (1969) described the morphometric characters of *Rita rita* from river Ganga at Varanasi and Mirzapur; and considered that the samples were derived from a homogeneous population and observed that the total length had high degree of correlation with various body measurements.

In *Lactarius lactarius* (Schneider), Apparao(1966) studied the growth of various body parts in relation to total length and observed the maximum rate of growth in standard length and minimum in the height of caudal peduncle in relation to total length. Chondar (1973) worked on *Gadusia chapra* and reported different racial stocks in this species inhibiting the same water body. Chonder (1976)also observed that the population of *Gadusia chapra* of Keetham lake at Agra could be distinguished from that of river Ganga in and around Allahabad in five measurable and twelve countable characters.

Singh and Dobriyal (1983) described the morphometric characters and their relationship in hillstream catfish *Pseuecheneis sulcatus* (McClelland) and found that all the body parts grow in accordence with the total length of fish and also found that the ratio of total length/ standard length was lowest (1.2), while eye diameter was highest (87.71). Chaudhary and Dwivedi (1984) described the morphometric characters of *Lactarius lactarius* and reported that the preanal region and body depth grows faster than the head. Meng and Stocker (1984) separated the stock of *Clupea harengus pallasi* employing twelve morphometric and meristic characters from different waters. Nautiyal and Lal (1988) conducted their studies on the specimens of *Tor putitora* (Ham.) from the two ecologically different water bodies, i.e., from the river Alaknanda and rivulet Nayar, and reported that only total length and body depth relationship differed significantly in the specimens collected from these two rivers.Gupta (1989) in *Eleutheronema tetradactylus* from four different areas *viz.*, Hooghly and Matlah estuaries, Chilka lake and Digha coast studied seventeen morphometric characters and reported that all populations were different from each other in one or more morphometric characters.

Various authors have conducted their studies on hillstream fish including *Noemacheilus montanus* (Dobriyal and Bahuguna, 1987), *Tor tor* and *Tor putitora* (Pandey *et al.*,1995) and concluded that all the body parts grow in accordance with increase in total length of fish. In *Crossocheilus latius latius*, Pokhriyal and Singh (1992) studied the interrelationships of different morphometric characters and found that preanal region grows faster than prepelvic region and predorsal and dependent variables increase simultaneously with the increase in the independent variable because of significant correlation between these two types of variables. Tandon *et al.*, (1993) studied the morphometry of *Cirrhina reba* and found that more than fifty percent characters belong to intermediate category.

Pandey and Nautiyal (1997) worked on meristic and morphometric characters of two Schizothoracids, *Schizothorax richardsonii* and *S. plagiostomus* and reported that *S. plagiostomus*, on the basis of larger anal fin length (AFL) and smaller anal to caudal fin base length (A-CFBL) can be distinguished it from *S. richardsonii*. Bhatt *et al.*, (1998a,b) conducted comparative study on morphometric characters of Himalayan Mahseer *Tor putitora* (Ham.) between Ganga and Gobindsagar reservoir stocks and standard length, anal fin length, caudal fin length, predorsal distance and preanal distance in proportion of total length and postorbital distance and preorbital distance in proportion to head length of mahseer of river Ganga and Gobindsagar were found to be closely related.

Singh and Singh (2000) conducted their studies on morphometric relationships of *Labeo calbasu* samples collected from the river Ganga at Allahabad in relation to total length, standard length and head length and considered standard length to be the most

correlated body parameter with total length and the lowest correlation was found between head length and eye diameter.

Gulathi and acharya (2001) studied the morphometric and meristic characters of Splendid silver belly *Leognathus splendens* (Cuvier) from Bombay coast sexwise and found no significant difference between the sexes in morphometric and any deviation in the meristic characters. Dutt and Kumar (2001) worked on the growth rate of different body parts in male and female *Puntius sarana* (Ham.) and observed that these characters did not show any significant heterogeneity except in snout length. They reported that the growth rate of snout length was found to be higher in females than in males.

Morphometric data of *Puntius sophore* was compiled. It was observed that the standard length was 82.101, head length 23.768, snout length 5.88, eye diameter 8.49, postorbital length 10.84, predorsal length 38.402, prepelvic length 40.66, preanal length 59.21, maximum body depth 30.17 and caudal length 17.38 in percentage of total length and snout length 23.302, eye diameter 33.31 and postorbital length 43.66 in percentage of head length.

This was observed that all body parts increase simultaneously with total length of fish. The ratio of total length and standard length was lowest (1.203) while total length and snout length was highest (18.23).

For *Puntius sophore* Day(1878) described the length of head 4.5, height of body 3.5 in the ratio of total length and eyes 3.0 to 3.25 in the ratio of head length. According to the present observation the head length was 3.72 to 4.375, body depth 2.9 to 3.64 in ratio of total length and eye diameter 2.6 to 3.37 in ratio of head length. The dorsal fin arises slightly before the ventral and midway between the end of the snout and root of

caudal fin. This observation supports the findings of Day (1878) who reported the same condition in this species. Jayaram (1981) Srivastava (1998) also studied the morphometrics of this species.

While interpreting certain characters the present observations slightly differed from those of Day (1878), Jayaram (1981) and Srivastava (1998). The above differences in morphometric characters may be due to different ecological conditions, which have a bearing on the growth of body parts.

The relationship for various body measurements revealed that the dependent variables (standard length , head length, snout length , eye diameter , postorbital length , predorsal length, prepelvic length, preanal length, maximum body depth and caudal length) were highly correlated with the corresponding independent variables (total length, standard length and head length) which implied that the former increased simultaneously with the increase of latter. The linearity of regression was proved by analysis of variance (ANOVA) . The significance of morphometric relationships between the independent and dependent variables was tested statistically and found significant at 1% level. Similarly in all cases the correlation coefficient was recorded high, indicating a high degree of correlation in growth between the body parameters, i.e., independent and dependent variables.

Table. 1.1: Morphometric measurements of *Puntius sophore* (mean with standard deviation in mm)

Size group	*Total length*	*Standard length*	*Head length*	*Snout length*	*Eye diameter*	*Post orbital length*
41 - 50	47.5 ± 1.8	38.1 ± 1.5	9.9 ± 1.1	2.9 ± 0.3	4.2 ± 0.4	4.4 ± 1.6
51 - 60	56.7 ± 2.6	45.9 ± 1.8	13.5 ± 0.8	3.1± 0.2	4.1± 0.2	5.7± 1.8
61 - 70	66.2 ± 2.7	53.8 ± 1.9	14.9± 0.1	3.5± 0.5	4.5± 0.6	6.7± 1.2
71 - 80	75.1 ± 2.8	60.6 ± 2.8	16.1 ± 0.8	4.2± 0.3	6.0± 0.4	7.9± 1.3
81 - 90	85.2± 2.8	67.6 ± 0.02	18.8 ± 0.8	4.4 ± 0.4	6.4± 0.4	8.6 ± 1.6
91 - 100	95.2 ± 2.8	76.3 ± 2.0	20.3 ± 0.4	5.1 ± 0.2	7.2 ± 0.5	11.4 ± 2.8
101 - 110	104.7± 2.5	85.6 ± 2.4	21.1± 0.3	5.2 ± 0.3	7.4± 0.7	14.1 ± 2.5
111 - 120	114.0± 1.8	95.5 ± 1.5	21.3 ± 0.4	6.5 ± 0.5	8.5± 0.5	15.1 ± 1.1
Total	77.5 ± 14.5	62.4 ± 11.6	16.9 ± 2.7	4.1 ± 0.7	5.7 ± 1.2	11.8 ± 2.5

Size group	*Predorsal length*	*Prepelvic length*	*Preanal length*	*Max. body depth*	*Caudal length*
41 - 50	14.7± 0.7	15.7± 0.7	25.6 ± 2.4	12.4 ± 0.4	9.4 ± 1.2
51 - 60	19.9 ± 2.5	21.1± 2.6	31.9± 2.8	15.9 ± 1.0	10.8 ± 1.4
61 - 70	24.9 ± 1.3	26.2± 1.4	38.1 ± 2.7	18.8 ± 0.7	12.5 ± 1.4
71 - 80	28.1 ± 1.7	29.6 ± 1.9	43.3 ± 3.0	21.1 ± 0.5	14.6 ± 1.3
81 - 90	33.1 ± 1.5	34.8± 1.6	50.4 ± 2.9	22.8 ± 0.8	17.5 ± 1.0
91 - 100	36.8 ± 2.0	38.6± 2.1	55.9 ± 2.5	28.0 ± 2.1	18.8 ± 1.3
101 - 110	40.2 ± 2.2	42.3 ± 2.2	60.6 ± 3.6	30.9 ± 0.4	19.1 ± 1.3
111 - 120	43.8 ± 1.2	47.3 ± 0.8	62.3 ± 4.0	31.5± 0.5	19.5 ± 0.8
Total	29.4 ± 6.3	30.9 ± 6.6	45.0 ± 9.3	21.8± 4.4	15.1 ± 3.2

Table 1.2: Body parts in ratio of total length, standard length and head length of *Puntius sophore* (average values bracketed)

Body parts	*IN RATIO OF*		
	Total length	*Standard length*	*Head length*
Standard length	1.18 - 1.24 (1.203)		
Predorsal length	2.36 - 2.73 (2.55)	2.09 - 2.235 (2.104)	
Prepelvic length	2.307 - 2.58 (2.41)	1.95 - 2.12 (1.995)	
Preanal length	1.58 - 1.85 (1.66)	1.305 - 1.46 (1.37)	
Caudal length	5.0 - 6.38 (5.71)	4.06 - 5.41 (4.72)	
Maximum body depth	2.9 - 3.64 (3.25)	2.35 - 2.92 (2.64)	
Head length	3.72 - 4.37 (4.14)	3.11 - 3.72 (3.408)	
Eye diameter	11.16 - 13.87 (12.51)	9.14 - 11.87 (10.31)	2.66 - 3.375 (2.968)
Snout length	16.25 - 20.3 (18.23)	12.80 - 16.25 (14.82)	4.0 - 4.75 (4.28)
Postorbital length	8.28 - 10.0 (9.09)	6.57 - 9.57 (7.75)	2.076 - 2.712 (2.295)

Table 1.3: Body parts in percentage ratio of total length, standard length and head length of *Puntius sophore* (average values bracketed)

Body parts	*IN PERCENTAGE OF*		
	Total length	*Standard length*	*Head length*
Standard length	80.0 - 82.92 (82.101)		
Predorsal length	37.02 - 41.11 (38.402)	45.2 - 50.66 (49.96)	
Prepelvic length	40.57 - 43.33 (40.66)	47.22 - 52.38 (48.45)	
Preanal length	58.33 - 62.72 (59.21)	70.58 - 75.82 (73.26)	
Caudal length	16.21 - 20.88 (17.38)	18.46 - 23.41 (21.57)	
Maximum body depth	27.47 - 34.48 (30.17)	34.24 - 42.58 (37.65)	
Head length	22.72 - 25.71 (23.76)	27.72 - 32.72 (29.42)	
Eye diameter	6.79 - 9.72 (8.49)	8.23 - 12.06 (10.11)	29.62 - 36.84 (33.31)
Snout length	4.85 - 6.66 (5.88)	6.09 - 8.47 (7.17)	20.0 - 26.31 (23.302)
Postorbital length	9.78 - 12.19 (10.84)	10.76 - 14.92 (13.07)	40.0 - 50.01 (43.66)

Fig. 1.4 Statistical data on the regression analysis, correlation coefficient and 't' test between various body parameters

Variable		*Regression equation* $Y = a + b X$	*Correlation coefficient (r)*	*Observed 't' value* $(t_{0.01})$
Independent (X)	*Dependent (Y)*			
Total lt.	Standard lt.	Y = 0.6139 + 0.7967 X	0.9937	222.015*
Total lt.	Head lt.	Y = 3.1105+ 0.1781 X	0.9329	64.965*
Total lt.	Snout lt.	Y = 0.4454 + 0.4695 X	0.8724	44.761*
Total lt.	Eye diameter	Y = -0.0438 + 0.0742 X	0.89161	49.374*
Total lt.	Postorbital lt.	Y = 2.6212 + 0.2058 X	0.9428	71.693*
Total lt.	Predorsal lt.	Y = -0.5003 + 0.3912 X	0.9637	90.512*
Total lt.	Prepelvic lt.	Y = -0.6539 + 0.4125 X	0.9630	89.633*
Total lt.	Preanal lt.	Y = -3.1729 + 0.6214 X	0.9674	95.827*
Total lt.	Max. body depth	Y = -0.3850 + 0.2861 X	0.9344	65.873*
Total lt.	Caudal lt.	Y = -0.6139 + 0.2032 X	0.9141	56.539*
Standard lt.	Head lt.	Y = 3.1105 + 0.1781 X	0.9329	64.967*
Standard lt.	Snout lt.	Y = 0.4090 + 0.0470 X	0.8732	44.927*
Standard lt.	Eye diameter	Y = -0.0190 + 0.0919 X	0.8843	47.487*
Standard lt.	Postorbital lt.	Y = 2.9031 + 0.0952 X	0.8088	34.493*
Standard lt.	Predorsal lt.	Y = -3.3728 + 0.5248 X	0.9598	85.749*
Standard lt.	Prepelvic lt.	Y = -3.5171 + 0.5512 X	0.9599	85.867*
Standard lt.	Preanal lt.	Y = -3.0587 + 0.7701 X	0.9638	90.648*
Standard lt.	Max. body depth	Y = -0.6088 + 0.3591 X	0.9402	69.201*
Standard lt.	Caudal lt.	Y = 0.1077 + 0.2409 X	0.8647	43.1735*
Head lt.	Snout lt.	Y = -0.1456 + 0.2481 X	0.8803	46.532*
Head lt.	Eye diameter	Y = -0.7384 + 0.3813 X	0.8742	45.149*
Head lt	Postorbital lt.	Y = 1.5116 + 0.4330 X	0.8769	45.77*

*Highly significant correlation

Table 1.5(a) : ANOVA between Total length and dependent variable in *P. sophore*

TOTAL LENGTH AND STANDARD LENGTH

	df	*SS*	*MS*	*F*
Regression	1	84545.2	84545.2	49136.9
Residual	629	1082:26	1.7206	
Total	630	85627.5		

TOTAL LENGTH AND HEAD LENGTH

	df	*SS*	*MS*	*F*
Regression	1	4227.62	4227.62	4218.12
Residual	629	630.417	1.00225	
Total	630	4858.04		

TOTAL LENGTH AND SNOUT LENGTH

	df	*SS*	*MS*	*F*
Regression	1	289.138	289.138	2002.76
Residual	629	90.8084	0.14437	
Total	630	379.946		

TOTAL LENGTH AND EYE DIAMETER

	df	*SS*	*MS*	*F*
Regression	1	735.073	735.073	2438.86
Residual	629	189.58	0.3014	
Total	630	924.653		

TOTAL LENGTH AND PREDORSAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	20285.3	20285.3	8191.93
Residual	629	1557.56	2.47625	
Total	630	21842.9		

TOTAL LENGTH AND PREPELVIC LENGTH

	df	*SS*	*MS*	*F*
Regression	1	22558.2	22558.2	8041.18
Residual	629	1764.56	2.80534	
Total	630	24322.8		

TOTAL LENGTH AND PREANAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	51181.4	51181.4	9181.12
Residual	629	3506.45	5.57464	
Total	630	54687.9		

TOTAL LENGTH AND MAXIMUM BODY DEPTH

	df	*SS*	*MS*	*F*
Regression	1	10902.3	10902.3	4330.69
Residual	629	1583.48	2.51745	
Total	630	12485.8		

TOTAL LENGTH AND POST ORBITAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	5644.27	5644.27	5031.52
Residual	629	705.601	1.12178	
Total	630	6349.87		

TOTAL LENGTH AND CAUDAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	5502.19	5502.19	3197.82
Residual	629	1082.26	1.7206	
Total	630	6584.45		

Table 1.5(b) : ANOVA between Standard length and dependent variable in *P. sophore*

STANDARD LENGTH AND HEAD LENGTH

	df	*SS*	*MS*	*F*
Regression	1	4227.62	4227.62	4218.12
Residual	629	630.417	1.00225	
Total	630	4858.04		

STANDARD LENGTH AND SNOUT LENGTH

	df	*SS*	*MS*	*F*
Regression	1	294.476	294.476	2020.09
Residual	629	91.6916	0.14577	
Total	630	386.168		

STANDARD LENGTH AND EYE DIAMETER

	df	*SS*	*MS*	*F*
Regression	1	723.025	723.025	2255.56
Residual	629	201.628	0.32055	
Total	630	924.653		

STANDARD LENGTH AND PREDORSAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	23567.7	23567.7	7359.69
Residual	629	2014.22	3.20226	
Total	630	25581.9		

STANDARD LENGTH AND PREPELVIC LENGTH

	df	*SS*	*MS*	*F*
Regression	1	26000.8	26000.8	7380.02
Residual	629	2216.05	3.52313	
Total	630	28216.8		

STANDARD LENGTH AND PREANAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	50747.6	50747.6	8213.91
Residual	629	3886.12	6.17824	
Total	630	54633.7		

STANDARD LENGTH AND MAXIMUM BODY DEPTH

	df	*SS*	*MS*	*F*
Regression	1	11036.1	11036.1	4788.51
Residual	629	1449.66	2.30471	
Total	630	12485.8		

STANDARD LENGTH AND CAUDAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	4966.06	4966.06	1864.32
Residual	629	1675.49	2.66374	
Total	630	6641.55		

STANDARD LENGTH AND POST-ORBITAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	775.125	775.125	1190
Residual	629	409.708	0.65136	
Total	630	1184.83		

Table 1.5(c) : ANOVA between Head length and dependent variable in *P. sophore*

HEAD LENGTH AND SNOUT LENGTH

	df	*SS*	*MS*	*F*
Regression	1	299.236	299.236	2165.12
Residual	629	86.9323	0.13821	
Total	630	386.168		

HEAD LENGTH AND EYE DIAMETER

	df	*SS*	*MS*	*F*
Regression	1	706.589	706.589	2038.13
Residual	629	218.064	0.34668	
Total	630	924.653		

HEAD LENGTH AND POST ORBITAL LENGTH

	df	*SS*	*MS*	*F*
Regression	1	911.233	911.233	2094.89
Residual	629	273.601	0.43498	
Total	630	1184.83		

CHAPTER IV

LENGTH-WEIGHT RELATIONSHIP

LENGTH-WEIGHT RELATIONSHIP

INTRODUCTION

The study of length-weight relationship is a significant tool in fishery biology. Prediction of potential yield and determination of proper sizes of fish to harvest for maximum sustained yield are directly related to fish weight. These studies are conducted primarily to facilitate the conversion of one measure to another and also for calculating condition factor to know the wellbeing of fish and used to measure variation from the expected weight or length of individual or relevant group of individuals (LeCren,1951). The relationship was found useful in differentiating small taxonomic units, as variation may occur within population of different localities (LeCren,1951; Chondar, 1972). The study of length-weight relationship is also known for its practical utility in fish management and conservation because these two variables are useful in deriving index of condition of fish studied.

Allen (1938) reported that the length-weight relationship of a fish follow cube law, if fish maintain the same shape and specific gravity throughout life. LeCren (1951) has reviewed in detail the methods employed in estimating the length-weight relationship of fishes with a clear exposition of the superiority of the equation of the general parabola ($W = aL^b$) over that of cubic parabola ($W = CL^3$) where 'W' and 'L' are weight and length respectively, 'a' is a constant equivalent to 'C' and 'b' another constant to be calculated empirically from the data. The change in 'b' value is influenced by a number of factors

viz., age, sex, maturity, season, nutritive condition of the environment, physiological conditions of the fish at the time of collection etc.

The relative condition factor (Kn) has been considered to be an important aspect of fishery biology. The condition factor is an expression of the condition in which the individual fish is, or has been during a certain period. The condition of a fish is an indicator of gonad development, robustness, suitability ofthe environment, differential growth of different ages, breeding behaviour and wellbeing. The value is also useful in explaining differences among individuals of the same length, differences arising from seasonal changes in relation to the age and sex of the fish, and differences between conditions of the individuals of the same species in different water bodies. LeCren (1951), reported that Kn value is affected by length as well as several other factors like breeding, food supply, and degree of parasitism. The Kn value appears to increase steadily in most fish species upto a certain size, after which there is a reduction in the rate of increase in length but the weight increases.

The length-weight relationship of several species of fishes have been studied by a number of workers including Hile (1936), Thompson (1942), Hart (1946), Kesteven (1947), Beckman (1948), Chacko and Ganapati (1951), Jhingran (1952), Prabhu (1955), Sarojini (1957, 1958), Pillay (1958), Tandon (1962), Baseeruddin and Nayar (1962), Jhingran (1968), Lal (1969), Narsimhan (1970), Kamal (1971), Krishnamoorti (1971), Venketaswerlu and Benerjee (1971), Chonder (1972, 1973), Jhonson and Horton (1972), Rao and Rao (1972), Ramakrishnaiah (1972), Devraj (1973), Sinha (1972), Vinci and Nair (1974), Rangaswami (1976), Rita Kumari and Nair (1978), Pathani (1979), Soni and Kathal (1979), Lal and Mishra (1980), Quadri and Mir (1980), Reddy (1981), Sugunan

and Vinci (1981), Srivastava and Pandey (1981), Cinco (1982), Sareen *et al.*, (1983, 1984), Thakre and Bapat (1984), Gowda (1984), Dutt *et al.*, (1985), Nautiyal (1985), Dasgupta (1988), Johal *et al.*, (1989), Bolger and Cannolly (1989), Kolekar and Choudhary (1989), Farooqh and Siddiqui (1991), Basheer *et al.*,(1993), Pandey and Lal (1995), Petrakis and Stergion (1995), Dhanze and Dhanze (1996), Kangur (1996), Mitra and Mandal (1997), Sarkar *et al.*, (1998), Mandal *et al.*, (1998), Sadashiv (2000), Pandey (2001), Doddamani *et al.*, (2001), Mitra (2001), Khan et al., (2001), Rizvi et al., (2002) and Sivakami et al., (2001).

The present chapter deals with the study of length-weight relationship of *P. sophore* from Ganga river system at Allahabad.

OBSERVATIONS

The length-weight relationship and correlation coefficient (r) obtained for both the sexes separately, for different season and for combined relationship for the two sexes are presented in Table 2.1 and given below :

(I) Sex-wise and Pooled data

(i) Male

Logarithmic equation, $Log\ W = -3.7611 + 2.4188\ Log\ L$

Parabolic equation, $W = 0.000173116\ L^{2.4188}$

(r = 0.85090)

(ii) Female

Logarithmic equation, $Log\ W = -4.1546 + 2.6499\ Log\ L$

Parabolic equation, $W = 0.000070035\ L^{2.6499}$

(r = 0.92842)

(iii) Pooled data

Logarithmic equation, $Log\ W = -4.1812 + 2.6584\ Log\ L$

Parabolic equation, $W = 0.000065882\ L^{2.6584}$

(r = 0.92083)

(II) Season wise

(i) For male during winter

Logarithmic equation, $Log\ W = -3.2675 + 2.1446\ Log\ L$

Parabolic equation, $W = 0.00054002\ L^{2.1446}$

(r = 0.88772)

(ii) For male during summer

Logarithmic equation, $Log\ W = -2.7872 + 1.8988\ Log\ L$

Parabolic equation, $W = 0.0016321 87\ L^{1.8988}$

(r = 0.77244)

(iii) For male during monsoon

Logarithmic equation, $Log\ W = -4.4678 + 2.8021\ Log\ L$

Parabolic equation, $W = 0.000034052\ L^{2.8021}$

(r = 0.85924)

(iv) For female during winter

Logarithmic equation, $Log\ W = -3.3888 + 2.2254\ Log\ L$

Parabolic equation, $W = 0.000408498\ L^{2.2554}$

(r = 0.92608)

(v) For female during summer

Logarithmic equation, $Log\ W = -3.2557 + 2.1963\ Log\ L$

Parabolic equation, $W = 0.000554932\ L^{2.1963}$

$(r = 0.88258)$

(vi) For female during monsoon

Logarithmic equation, $Log\ W = -4.7332 + 2.9522\ Log\ L$

Parabolie equation, $W = 0.000018481\ L^{2.9522}$

$(r = 0.95306)$

The regression equations and values of correlation coefficient (r) are suggestive of a close relationship between length and weight of fish. The perusal of length-weight equations derived for *Puntius sophore* reflects the fact that the weight of this species increases slightly less than the cube of its length as the value of regression coefficient 'b' was always found less than 3 (1.8988 to 2.9522). The value of regression coefficient 'b' varied from 1.8988 to 2.8021 in male *Puntius sophore* with a minimum 1.8988 in summer and maximum 2.8021 in monsoon. For female sex, it varied from 2.1963 to 2.9522 with a maximum during monsoon (2.9522) and minimum during summer (2.1963).The value of b was recorded 2.6584 for pooled data. Significance of regression coefficient (b) was also tested by applying t-test and it was observed that all the values are significant at 0.05% level (Table 2.1).

The regression equations and the values of correlation coefficient (r) was positively correlated with the length and weight. The values of correlation coefficient (r) was high between length and weight of *Puntius sophore* and it varies from 0.77244 to 0.95306. Analysis of variance (ANOVA, 'F' test) revealed that per millimeter increase in the total length was significant for per gram gain in weight of fish. The 'F' test shows that the values of F for all the relationships are significant at 1% level (Table 2.2).

Graphical representation of the calculated log weight against observed log length gave a straight line, whereas their numerical values follow a parabolic curve (Figs 2.1 to 2.6) which showed an increase in the length with the gradual increase in the weight.

The monthly and seasonal mean values of Kn were calculated separately for males and females (Table 2.3 and 2.4) and plotted graphically in Fig 2.7. For both male and female *Puntius sophore*, the highest value of Kn was recorded in July 1.134 and 1.205, and lowest in October 0.861 and 0.757 respectively. The higher Kn value during monsoon season, 1.058 and 1.123 for male and female fishes (Table 2.4) corresponds with the heavy growth of gonads which sharply declined after spawning in the month of September when spent fishes were encountered in large numbers.

Fluctuations in relative condition factor at different lengths for different sexes were also studied. The mean Kn values of each size group of both males and females are presented in Table 2.5 and graphically shown in Fig. 2.8. The Kn values showed an irregular trend in various size groups and was found to be high in the youngest size group 41-50 mm for both the sexes. The fluctuations in the relative condition factor at different lengths of male and female fishes may be attributed chiefly to breeding of fishes, i.e., weight of gonads and subsequent loss in condition due to spawning activity. The high Kn values in smaller size group may be attributed to the high feeding intensity.

DISCUSSION

A knowledge of the length-weight relationship of fish has vital importance in fishery science. In fisheries research, the length-weight relationship is useful for a number of purposes, particularly to estimate biomass from length-frequency data. Furthermore they allow, (i) estimation of average weight of the fish for a given length group (Beyer, 1987),

(ii) conversion of length-growth equations to corresponding weight-growth equivalently, and (iii) assessing the relative wellbeing of fish populations (Bolger and Conolly, 1989).

Length-weight relationship of a fish stock from a particular area is a very useful tool for the study of population dynamics and is an indicator of the general growth and condition of the population. The study of this aspect in fishes is of primary importance in obtaining yield equations (Richer, 1958), in estimating the number of fish landed and in comparing population in time and space (Chanchal *et al.*, 1978).

In recent years, the emphasis in fisheries research is to find out the possible mathematical relationship between the length and weight of fishes with a view to study the growth, gonadal development and management of the fish population (LeCren, 1951) and compare the life history at different locations (Petrakis and Stergion, 1995).

Length and weight of a particular species of fish are closely related to each other (LeCren, 1951). It is known that with increase in the length of fish, the weight also increases but in more rapid way, thereby showing that the weight of a fish is a function of length. Since length is a linear measure and weight is a measure of volume, it takes a cube form. Hence, the general expectation is that the weight of fish would vary as the cube of length (Sekharan, 1968; Pandey *et al.*, 1974 and Pathak, 1975); but the actual relationship may depart significantly from this (LeCren, 1951) as fishes normally do not retain the same shape throughout their life span. However, the variations from isometric growth (b=3) were found to be more (Beverton and Holt, 1957), and for an ideal fish which maintains its shape throughout, without any change, the value of b will be 3 (Allen, 1938). Verghese (1961), Talwar (1962) and various other workers have shown

that the value of regression coefficient 'b' either lies very close to the cube of length or differs significantly from this.

In the present study, the observed regression coefficient (b) values vary from 1.8988 to 2.8021 in males, and from 2.1963 to 2.9522 for females, and the value is 2.65847 for pooled data (Table 2.1). The higher values of correlation coefficient (r) ranging from 0.77244 to 0.95306 showed a close relationship between length and weight. The analysis of variance (ANOVA; F-test) between length and weight, sex-wise and season-wise showed significant values at 1% level (Table 2.2) which also confirm a close positive relationship between the two variables.

Various other workers have also studied the length-weight relationship and found that in most of cases fishes did not maintain the isometric pattern and the value of 'b' was either greater than 3 or smaller than 3 (Pillay, 1958; Lal and Dwivedi, 1965; Narsimhan, 1970; Majumdar, 1971; Lal, 1980 a, b; Nautiyal, 1985; Pokhriyal, 1986; Afser, 1991; Martin-Smith, 1996; Suryavanshi and Wagh, 1999; Pandey, 2001; Sivakami *et al.*, 2001).

During the course of present study the perusal of length-weight equation derived for *Puntius sophore* (Ham.) indicates the value of b, regression coefficient ranging from 1.8988 to 2.9522. Since the value of 'b' was always less than the cube of its length, indicating that the fish does not obey the cube law. The weight of this fish does not vary as the cube of its length. Thus there is departure from isometry (b=3) in the weight growth of *Puntius sophore*.

The departure from cube law may be due to several factors like sex, maturity, locality, metamorphosis, etc. According to Rounsefell and Everhart (1953), as the specific gravity and shape and body out line of the fish is subjected to changes, the cube

law need not always hold good. LeCren (1951) has stated that the length-weight relationship in fishes are probably related tothe seasonal variation since fat and water content of fish may vary according to temperature (Halver, 1972). Hughes et al., (1974) while studying the effect of growth on gill and accessory organs of *Saccobranchus* (=*Heteropneustes*) *fossilis* have mentioned that the compressed body shape of fish, a probable cause of the increase of the power function. Kaur and Nasar (1983) reported that the departure of 'b' values from 3 in *Channa gachua* may be due to the feeding habits of species and presence of good amounts of detritus along with vegetable matter in the stomach. Afser (1991) reported that 'b' value of some spawned female during monsoon period showed slight decrease (2.37) which is lower than 3 and does not follow cube law. Soni and Kathal (1979) reported the higher values of b (4.36) obtained in *Cirrhinus mrigala* is due to the presence of large quantities of sand and mud in the stomach, resulting in an increase in the weight.

In *Puntius sophore*, the value of exponent 'b' was observed below 3 and was maximum (2.9522) for females during monsoon and minimum (1.8988) for males during summer, which indicated the growth of fish was slightly more during monsoon and less during summer. The analysis of length-weight relationship was also found indicative of fish breeding as the value of b was highest during monsoon that might be due to great increase of gonads.

According to Muth and Smith (1974), the seasonal changes and notably the period during and immediately after spawning affects the length-weight relationship. Hart (1946) indicated an increase in fish length after the attainment of sexual maturity. Therefore, under these circumstances the value other than 3 indicate allometric growth.

According to Hile (1936) and Martin (1949), the value of 'b' usually fluctuate between 2.5 and 4.0 and in majority of cases the value was not equal to 3. The change in value shows allometric growth of the body due to the influence of numerous factors, *viz.*, seasonal fluctuations, change in physiological condition during spawning periods, gonadal development, sex, physicochemical conditions of the environments as reported by Sinha (1973).

Some workers have also observed the value of b<3 and do not agree with the cube law. Rangaswamy (1976) observed the value of 'b' 2.7234 for *Mugil cephalus*. In Catla catla, it was recorded 2.18 by Agarwal and Saxena (1979). The b value less than 1, in males of *Puntius sarana* was observed by Datta and Kumari (1976). Srivastava and Pandey (1981) observed the value of 'b' for the three Indian Major carps *viz., Labeo rohita, Catla catla* and *Cirrhinus mrigala* as 1.5141, 1.7923 and 1.5807 respectively. For male and female of *Plotosus canius* Sinha (1981) reported value of 'b' as 2.7459 and 2.8246 respectively. Prem Kumar *et al.*,(1984) reported value of 'b' as 2.9547 and 2.5369 for female and male of *Puntius amphibius*. Soni and George (1986) observed the value of 'b' as 2.759 for mudskipper (*Baleopthalamus dentatus*). Sunder (1985) found the value of exponent 'b' less than three for *Schizothorax curvifrons*. In catfish, *Wallago attu*, the exponent 'b' was found always below three by Kulshrestha *et al.*,(1990). Tandon *et al.*,(1993) reported value of 'b' as 2.9305 and 2.4980 for female and male of *Gadusia chapra* (Ham.). Rao and Rao (1972) in Godavari river and Pathak (1975) in Loni reservoir have reported 'b' values less than 3 for the major carp *Labeo calbasu*. Doddamani *et al.*,(2001) observed b values [illegible] *Stolephorus bataviensis* respectively. In *Clupisoma garua*, Pandey (2001) reported b

values 2.404 and 2.5019 for male and female fish respectively. Sivakami *et al.*,(2001) reported value of 'b' 2.626081 and 2.74387 in male and female *Priacanthus hamrur*.

The graphical representation of the length-weight data indicates the curvilinear and straight line relationship in respect of actual values and logarithmic transformation respectively for both the sexes and for pooled data (Figs. 2.1 to 2.6)

Another application of length-weight relationship is to gauge the health of the fish through use of relative condition factor (Kn) which is butressed on the above equation. Through its application, relative health of a species can be estimated. Relative condition factor (Kn) is reckoned as a pointer of general wellbeing of the fish. It expresses the condition of fish in numerical term.

The value of the coefficient of condition have been used widely by fishery investigators to express the relative robustness of fishes. They have been used as an adjacent to age and growth studies, to indicate the suitability of an environment for a species, by a comparison of the value for a specific locality.

Variation in the condition of the fish depends on various biological factors of the species. The specific gravity of fish changes considerably through the life depending upon the general condition, feeding condition and gonad development. Such changes in condition are generally analysed by means of 'Condition factor' (coefficient of condition) or ponderal index (Hile, 1936)

The variation in "Kn' values seems to be correlated with the feeding intensity of the fish. The seasonal variation in gonad weight caused by maturation is the main factor which seems to regulate the condition factor (LeCren, 1951). The other factor which seems to govern the rise and fall of 'Kn' value is the feeding rate of the fish (Ball and

Jones, 1960 and Bhatt, 1968). The value of Kn>1 points towards good health of fish and <1 otherwise (LeCren, 1951). Monthly variation in Kn values may be due to feeding and spawning acts of fishes. According to LeCren (1951) and Pillay (1958), the spawning season exert a considerable influence on the condition factor of fishes.

In the present study, the maximum value of 'Kn' was recorded during monsoon (Table 2.4) when fishes were at their peak health. Relative condition factor is dependent upon sexual maturity and feeding state of the fish. During monsoon months the fish are mature and their 'Kn' values goes up. After spawning, the value of Kn comes down as the eggs in female and milt in male fish are released. The high value of Kn may be an evidence of breeding season. Das and Pathani (1978) explained the high condition factor during breeding season. Parmeshwaran *et al.*,(1974) in *Labeo gonius* correlated the monthly fluctuations of the condition factor with its maturity cycle. Sunder *et al.*,(1979) observed the high relative condition factor during February, April, July and November in *Schizothorax niger* and observed that the fish was a prolonged spawner.

Table 2.1: Regression analysis and correlation coefficient on length-weight relationship of *Puntius sophore*

Condition	*Logarithmic equation*	*Parabolic equation*	*Value of 't'*	*Correlation Coefficient (r)*
Sex wise				
Male	Log W = -3.76116 + 2.4188 Log L	$W = 0.000173116\ L^{2.41887}$	23.52*	0.85090
Female	Log W = -4.15468 + 2.64992 Log L	$W = 0.000070035\ L^{2.64992}$	50.04*	0.92842
Season and Sex wise				
Male				
Winter	Log W = -3.2675 + 2.1446 Log L	$W = 0.00054002\ L^{2.1446}$	13.49*	0.88772
Summer	Log W = -2.78723 + 1.89884 Log L	$W = 0.001632187\ L^{1.89884}$	9.88*	0.77244
Monsoon	Log W = -4.46785 + 2.80215 Log L	$W = 0.000034052\ L^{2.80215}$	16.11*	0.85924
Female				
Winter	Log W = -3.38881 + 2.22547 Log L	$W = 0.000408498\ L^{2.25547}$	23.8*	0.92608
Summer	Log W = -3.25576 + 2.19637 Log L	$W = 0.000554932\ L^{2.19637}$	24.9*	0.88258
Monsoon	Log W = -4.73327 + 2.95221 Log L	$W = 0.000018481\ L^{2.95221}$	35.48*	0.95306
Pooled data (Sexes combined)	Log W = -4.18123 + 2.65847 Log L	$W = 0.000065882\ L^{2.65847}$	58.5*	0.920832

* All are significant at 0.05% level

Table 2.2: Analysis of variance (f-test) between length and Weight relationship for different sexes and seasons in *Puntius sophore*.

Parameters	*Source*	*df*	*SS*	*Ms*	*Observed F*	*Table F ($F_{0.01}$)**
[A] FOR DIFFERENT SEXES AND POOLED DATA						
(i) MALE	Regression	1	6.2084	6.2085	553.5997	6.63
	Residual	211	2.3663	0.0112		
	Total	212	8.5748			
(ii) FEMALE	Regression	1	20.15	20.15	2504	6.63
	Residual	401	3.227	0.008		
	Total	402	23.38			
(iii)	Regression	1	32.22	32.22	3424	6.63
POOLED	Residual	614	5.778	0.009		
DATA	Total	615	37.99			
[B] FOR DIFFERENT SEXES IN DIFFERENT SEASONS						
(i) MALE						
(a) Winter	Regression	1	1.2214	1.2214	182.1979	7.08
	Residual	49	0.3285	0.0067		
	Total	50	1.5499			
(b) Summer	Regression	1	0.8446	0.8446	97.6396	6.85
	Residual	66	0.5709	0.0086		
	Total	67	1.4155			
(c) Monsoon	Regression	1	3.6946	3.6946	259.5444	6.85
	Residual	92	1.3096	0.0142		
	Total	93	5.0042			
(ii) FEMALE	Regression	1	2.113	2.113	566.3	6.85
(a) Winter	Residual	94	0.351	0.004		
	Total	95	2.463			
(b) Summer	Regression	1	4.432	4.432	620.2	6.63
	Residual	176	1.258	0.007		
	Total	177	5.689			
(c) Monsoon	Regression	1	10.55	10.55	1259	6.63
	Residual	127	1.064	0.008		
	Total	128	11.61			

- All significant at 1% level of significance

Table 2.3 : Monthly fluctuations in the Relative condition factor (Kn) for different sexes in *Puntius sophore*

S. No.	*Month*	*Relative condition factor*	
		Male	*Female*
1	January	1.056±0.096	0.917±0.069
2	February	0.932±0.112	0.905±0.096
3	March	0.992±0.185	1.001±0.118
4	April	1.096±0.067	1.059±0.069
5	May	0.993±0.143	1.012±0.096
6	June	0.995±0.118	1.076±0.076
7	July	1.034±0.137	1.105±0.148
8	August	0.983±0.193	1.04±0.131
9	September	0.881±0.185	0.949±0.099
10	October	0.861±0.188	0.757±0.169
11	November	1.098±0.113	0.804±0.157
12	December	0.975±0.045	0.916±0.111

Table 2.4: Relative condition factor in different size groups for different sexes in *Puntius sophore*

Size - Group	*Relative Condition Factor*	
	Male	***Female***
41 - 50	1.2317	1.355
51 - 60	0.9867	0.8503
61 - 70	1.008	0.988
71 - 80	0.994	0.956
81 - 90	1.05	1.03
91 - 100	1.103	1.054
101 - 110	-	1.081
111 - 120	-	1.159
Average	0.676	1.007

Table2.5: Seasonal fluctuation in Relative Condition value (Kn) of *Puntius sophore*

S. No.	*Season*	*Relative Condition factor*	
		Male	*Female*
1	Winter (Dec. - Feb.)	0.977	0.924
2	Summer (March - June)	1.031	1.034
3	Monsoon (July - Aug.)	1.07	1.045
4	Autumn (Sept. - Nov.)	1.005	0.864

Fig 2.1: Length-weight relationship in male *P. sophore*

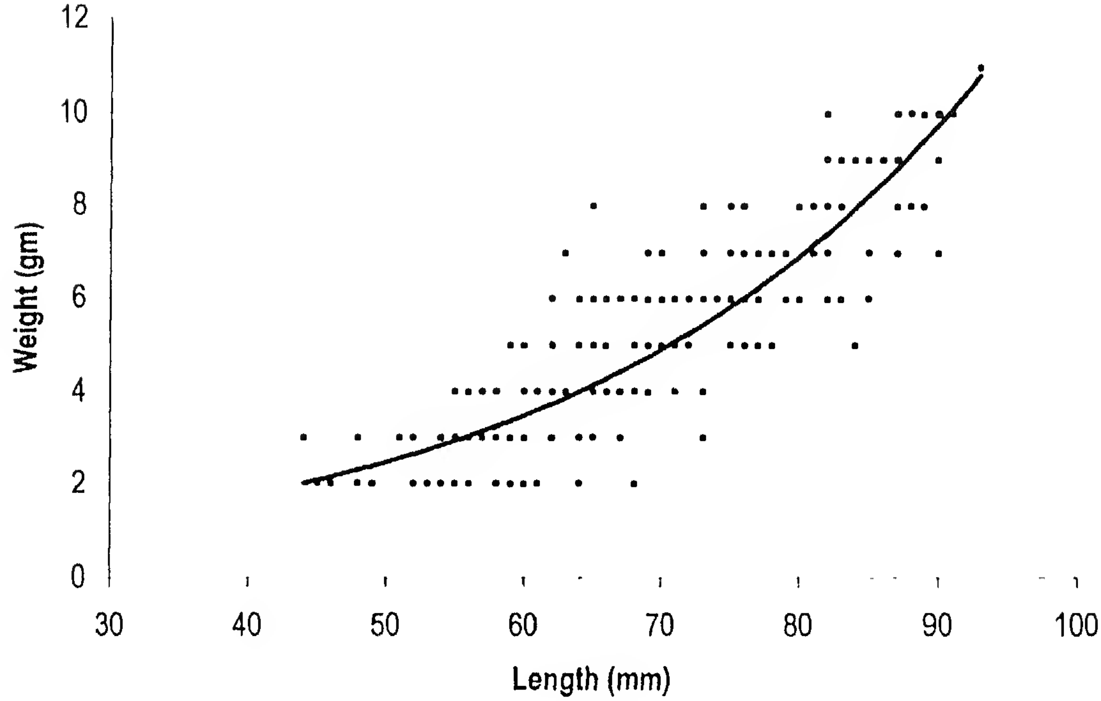


Fig. 2.2: Logarithmic length-weight relationship in male *P. sophore*

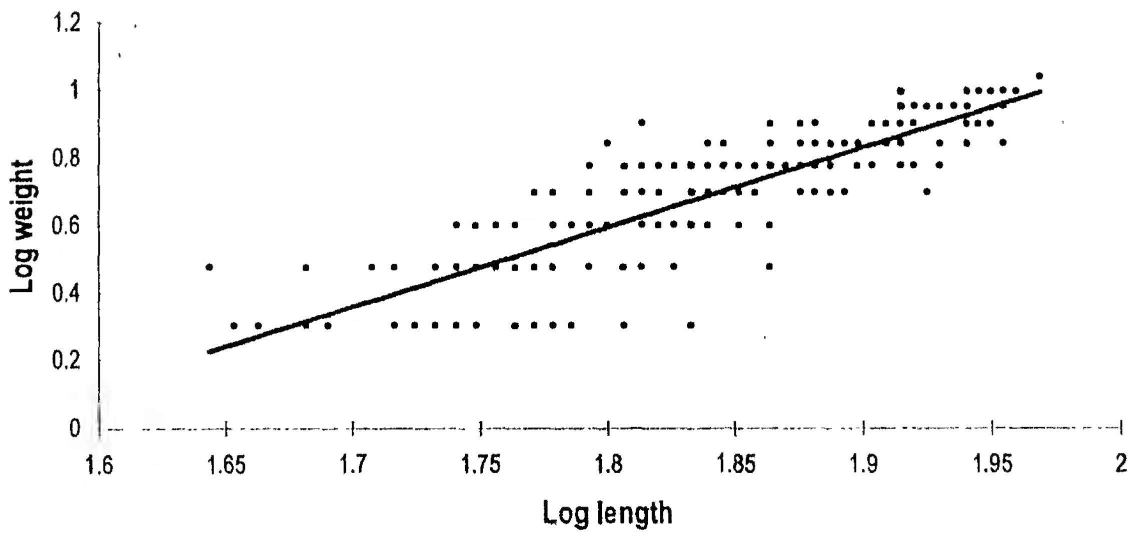


Fig 2.3: Parabolic length-weight relationship in female *P. sophore*

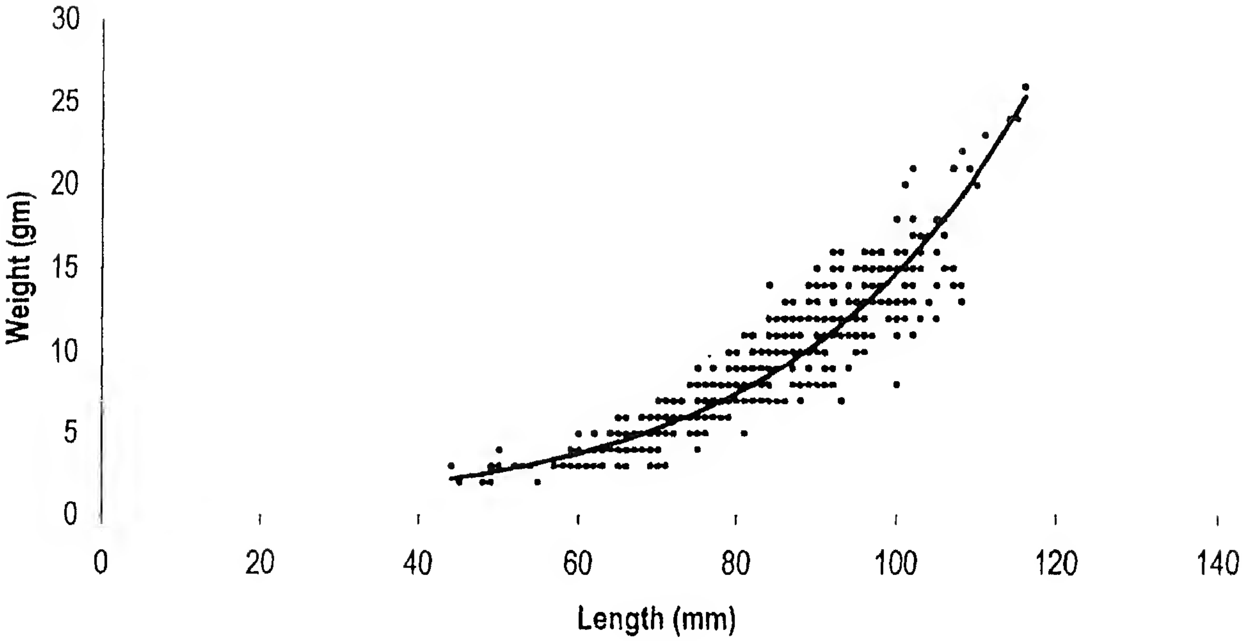


Fig 2.4: Logarithmic length - weight relationship in female *P.sophore*

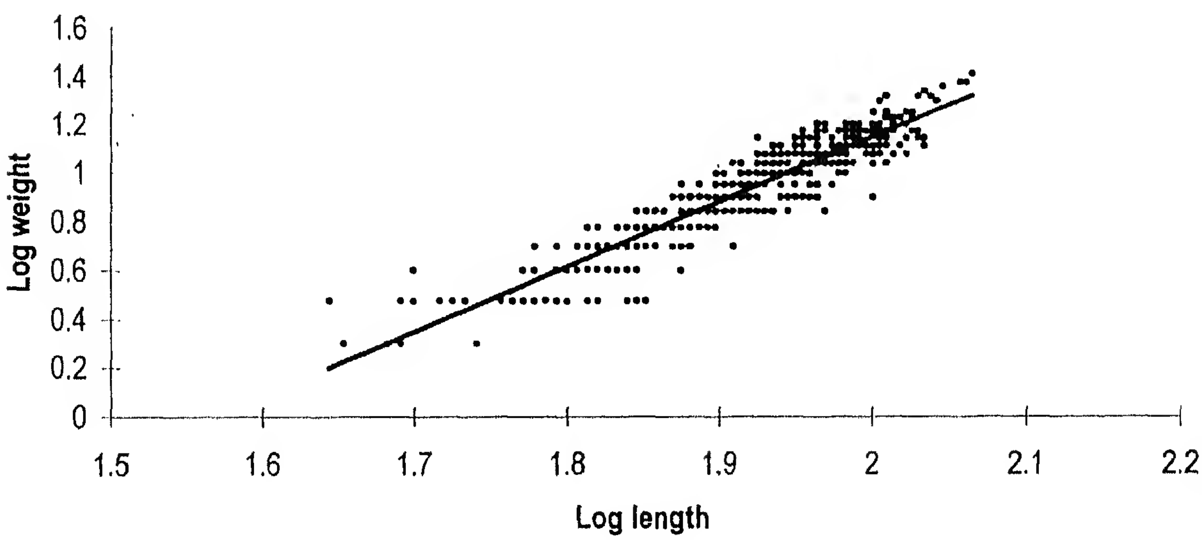


Fig. 2.5: Parabolic length - weight relationship in male and female *P. sophore*

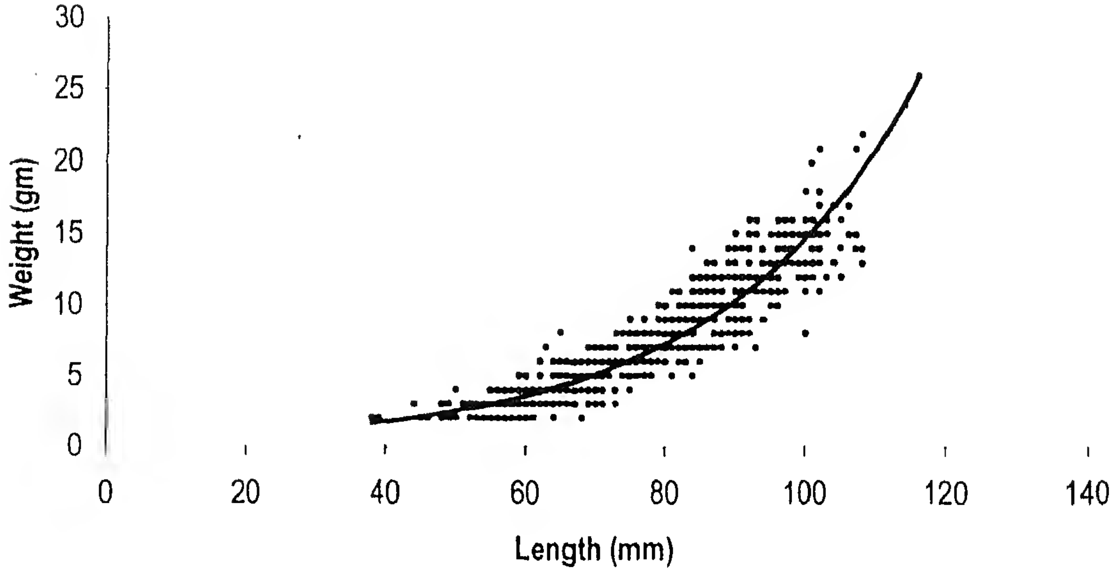


Fig 2.6: Logarithmic length-weight relationship in male and female *P. sophore*

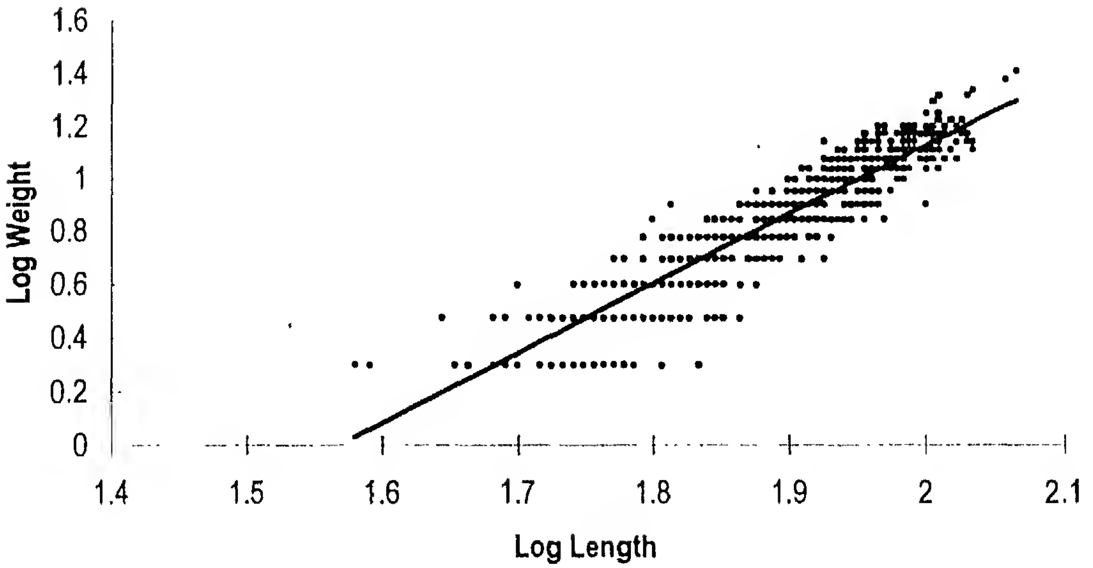


Fig.2.7 Monthly fluctions in the Relative condition factor (Kn) for different sexes in *P. sophore*

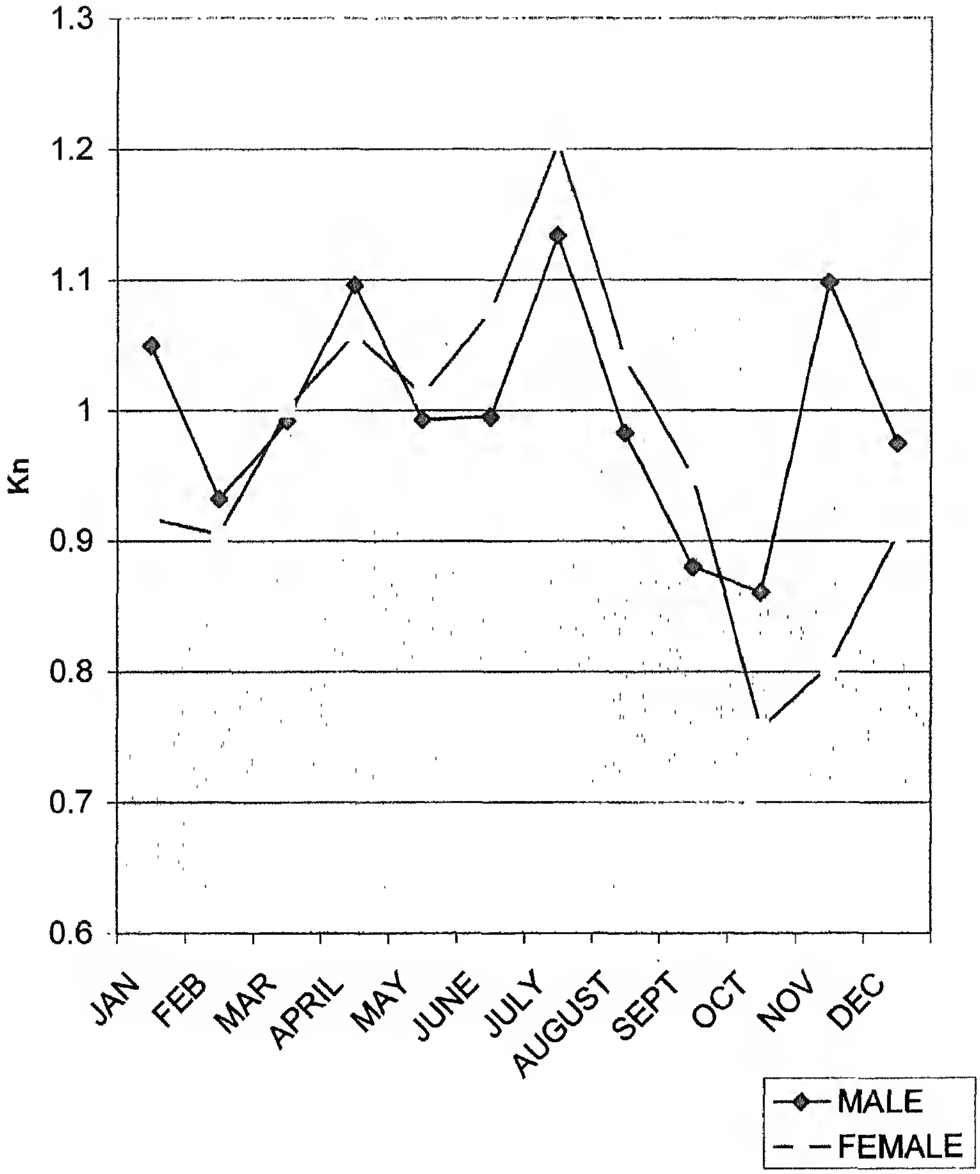
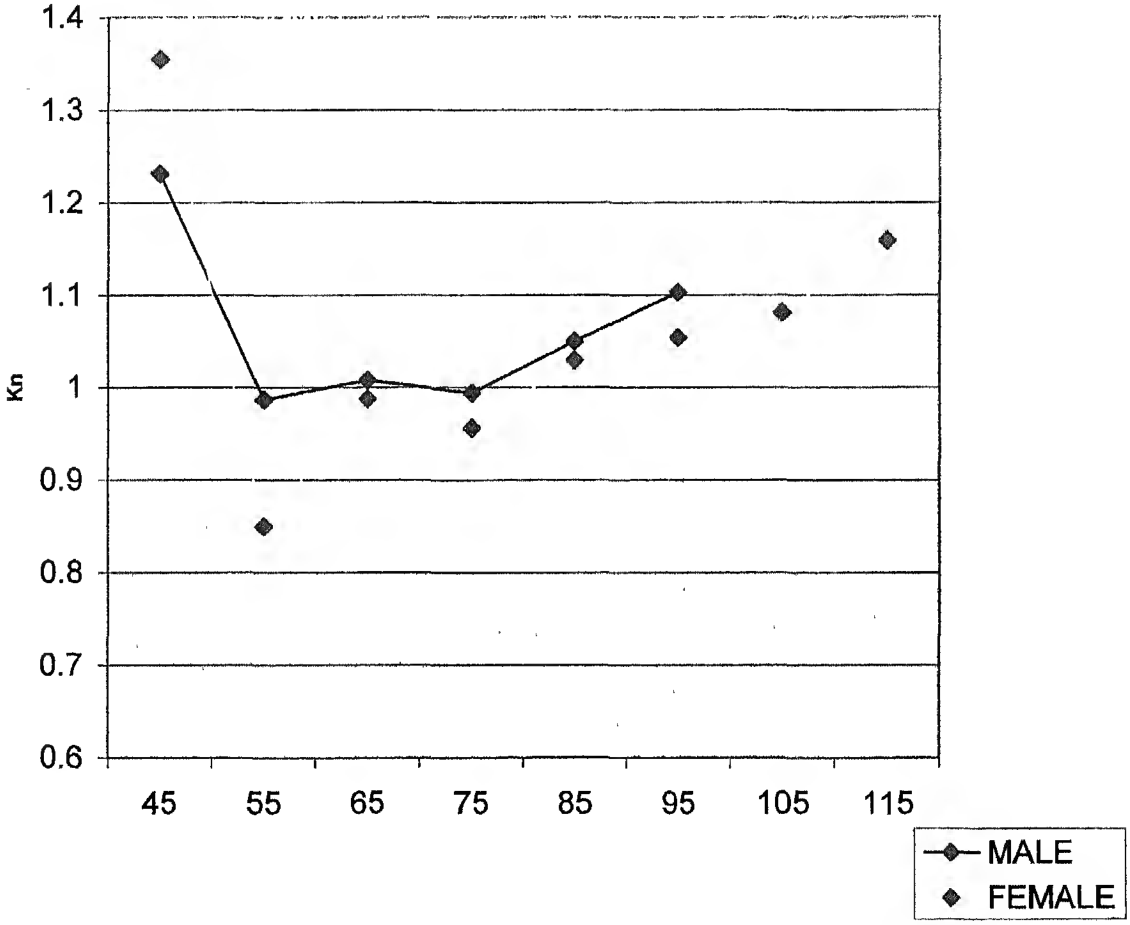


Fig.2.8 Relative condition factoir (Kn) in different size groups for different sexes in *P. sophore*



CHAPTER V

FOOD AND FEEDING HABITS

FOOD AND FEEDING HABITS

INTRODUCTION

The study of food and feeding habits of fishes is very important in fishery biology as it relates to various activities of the fish like shoaling behavior, migration and even the entire fishery. Food is the main source of energy and plays an important role in the life history of fishes by way of controlling their growth, fecundity and migration. The basic functions such as growth, development and reproduction takes place at the expense of energy which enter the organism in the form of food (Nikolsky, 1963) Variations in the seasonal and diurnal availability of the preference food organisms of various species of fish in any region may govern the horizontal and vertical movements of fish stocks. The knowledge of food and feeding is also necessary for culture fisheries.

The food and feeding habits of fishes also helps in finding out the distribution and abundance of a fish population and seasonal variation in condition factor. The food habits of some species may vary due to the availability of food in particular ecosystem. Hence this study gives an idea about food suitability for a particular fish in a particular niche.

Significant contribution on the food and feeding habits of fishes have been made by Sarbahi (1940), Swynerton and Worthington (1940), Suyehiro (1942), Mukherjee (1944), Chacko and Kurian (1948), Al-Hussani (1949), Bapat and Bal (1950), Hynes (1950), Chacko and Krishnamoorty (1950), Alikunhi (1952), Bhimachar and George (1952), Pillay (1952), Kapoor (1953), Sarojini (1954), Das and Moitra (1955a and b, 1956), Venkatraman (1960), Khanna (1961), Sharma and Chandy (1961), Kagwade

(1964), Kamal (1964, 1967), Desai and Karamchandani (1965), Sehgal (1966), Das and Subla (1969), Desai (1970), Qasim (1972), Verma *et al.*,(1974), Jyoti andMalhotra (1975), Jyoti (1976), Karamchandani and Mishra (1978), Pathani and Das (1979), Arvindan (1980), Nair and Sobhana (1980), Saxena (1980), Ramanathan and Natrajan (1980), Bahuguna and Singh (1981, 1984), Singh and Bahuguna (1983 a, b) Madhwal *et al.*,(1984), Nautiyal and Lal (1984), Dutta Munshi *et al.*,(1990), Dutta (1994), Ringer (1994), Sharma (1994), Cnappaz *et al.*,(1996), Biswas and Phukan (1996), Badapanda (1996), Nautiyal *et al.*, (1997),Rao *et al.*,(1998), Kishore *ėt al.*,(1998), Ghana and Waghray (1998), Philip (1998), Singh and Singh (2000), Pandey (2001), Pathak and Singh (2001), Kurian and Inasu (2001), Dasgupta (2001), Sivakami *et al.*,(2001), Rao and Rao (2002).

However, literature on the food and feeding habits of *Puntius sophore* in the reverie environment is scanty. Therefore, an attempt was made to study the food and feeding habit of *Puntius sophore* inhabiting the Ganga river system at Allahabad.

OBSERVATIONS

Qualitative and Quantitative analysis of food of Puntius sophore(Ham.)

Monthly and seasonal variations in the percental value of various food items in *Puntius sophore* have been recorded and presented in Tables 3.1, 3.2 and 3.3 and Figs. 3.1, 3.2 and 3.3. The gut content of this fish contain the following food items :

(a) ***Semi-digested unidentified green matter*** : Green matter was found as the most dominant food item. It was recorded in high percentage throughout the year. Its monthly percentage contribution was observed maximum in May (57.1%) and

minimum in January (11.5%) (Table 3.1). However, its seasonal value shows its higher percentage during summer and lowest during winter (Table 3.2).

(b) ***Algae*** : Algae formed the major bulk of the food in the gut contents during winter (61.1%). The percental value of algae was observed maximum in January (79.5%) and minimum during monsoon season (2.2%). It was observed that though this food was always the main food of fish, yet was relatively abundant during winter and minimum during monsoon. Among algae, *Ulothrix*, *Spirogyra*, *Zygnema*, *Mougeotia* were observed.

(c) ***Diatoms :*** Diatoms were recorded throughout the year. Maximum occurrence (9.5%) of this food item was recorded in November and minimum 2.8% in September. Diatoms in the gut were represented by genera such as *Synedra, Fragilaria, Navicula, Tabillaria, Cymbella, Diatoma, Nitzschia, Pinnularia, Gonatozygon and Gomphonema.*

(d) ***Insects and their larvae*** : This food component constituted the larvae, nymphs and parts of insects in the gut content. This food was observed more during monsoon season (25.9%) and less during winter (7.9%) (Table 3.2) and its monthly percental value shows its maximum value in July (27.6%) (table 3.1)

(e) ***Crustaceans and their larvae*** : This item comprised of different parts of crustaceans and their larvae. This food was also found maximum during monsoon (22.4%) and minimum during winter (3.8%) (Table 3.2). Some important crustaceans were identified as *Daphnia*, *Cyclops*, *Cypris* and *Eubranchipus*.

(f) *Miscellaneous* : Besides the above mentioned important food items other miscellaneous food items were also seen in the guts. Such items were recorded maximum 27.8% in August and minimum 4.6% in February (Table 3.1).

Gastrosomatis index (GaSI) : Gastrosomatic index (GaSI)with mean values was recorded for different months (Tab. 3.4 and fig. 3.4). The study of GaSI revealed that the feeding intensity attains its peak in January (3.59). The minimum value of GaSI was recorded during July (0.491) and August (0.209).

Feeding Index (FI) : The feeding index of each month was calculated by recording the number of full and 3/4 full guts out of the total number of guts recorded in a month and then their percentage was recorded for each fish separately. The feeding index was observed maximum in January (72.7%) and minimum in August (8%) (Table 3.5 and Fig 3.6).

Relative length of gut (RLG) : RLG values were tabulated for all the months of the year and ranged from 1.72 to 3.02 (Table 3.4 and Fig. 3.5).

DISCUSSION

The study of food and feeding habits of fishes has applied value in fishery science. Therefore, many authors have made attempt to study the food and feeding habits of fishes during different months and seasons of the year, as also of different stages from fry to adult. The knowledge of feeding behaviors is highly significant in the fishery biology investigations.

Das and Moitra (1955) have classified fishes on the basis of their actual diet into three primary groups *viz.*, herbivorous, omnivorous and carnivorous. According to their classification, the herbivorous fish consumes 75% plant food, carnivorous fish consumes

75% animal food, while the omnivorous fish consumes both animal and plant matter in a considerable amount. Nikolsky (1963) divided the adult fishes into three categories : (a) herbivorous and detriophagic (b) carnivorous, which feeds on insects and (c) Predators, which feed on fish. But this classification is very subjective because the majority of fishes feed on mixed diet.

During the present investigation it was observed that both plant and animal food was present in considerable amount in the gut contents of *Puntius sophore* (Table 3.2). As the fish consumes both animal and plant food, it may be called omnivorous. The amount of animal and plant food varies every month and depends on the season of the year. The annual percentage of food revealed that the fish consumes approximately 62.5% plant food and 37.5% animal food (Tab. 3.3) which is an evidence in support of its omnivorous nature.

Schaeperclaus (1933) classified the food of fishes as (i) main food stuff or natural food, which the fish under favorable conditions will choose in preference and by which it will thrive best, (ii) occasional food stuff *viz.*, food items that are well liked and consumed whether the opportunity is there (this type of food can be of relatively high nutritive value), (iii) emergency food stuff, which is taken when other food items were not available.

Nikolsky (1963) described the food of fishes into four categories which are : (a) main food or basic food which is the natural food taken and preferred by a fish under favorable conditions; (b) secondary food, which is consumed by the fish when available and present in the gut in small quantity throughout the year; (c) incidental food which

enters the gut by chance along with other items and is rarely seen in the gut contents and (d) obligatory food, which is consumed by the fish when the basic food is not available.

In the present case *Puntius sophore* is omnivorous and feeds on both animal and plant food. The percentage of plant and animal food during winter, summer and monsoon was 86.9 / 13.1, 64.3 / 35.7 and 36.5 / 63.5 respectively (Table 3.3). The data indicates that during winter and summer the basic food is algae and green matter while during monsoon the basic food of fish is animal matter, i.e., insects and their larvae and crustaceans and their larvae.

Diatoms were observed throughout the year in the gut contents of *Puntius sophore*, thus it formed the secondary food of this fish. The diatoms were observed maximum in November (9.5%) and minimum in September (2.8%). The annual percentage of diatoms was 6.24% (Table 3.1, Fig. 3.3). Rotifers were found in negligible percentage and were not observed throughout the year, hence may be considered as incidental food.

Parts of macrophytes, debris and detritus were considered as the obligatory food, because these were observed in fair percentage during monsoon when the basic food and secondary food items were flushed away due to heavy floods in the river. In other months, when basic and secondary food items were available in abundance the percentage of these food items were found much less (Table 3.1). Such items were recorded maximum in August (27.8%) and minimum in February (4.6%).

Nikolsky (1963) depending on the number of food items consumed by fish, classified the fishes into two groups : (a) stenophagic (feeding on a few different type of food) and (b) euryphagic (feeding on a variety of food).The overall food analysis of

Puntius sophore reveals that this fish feeds on a number of food item including algae, diatoms, insects and their larvae, crustaceans and their larvae, rotifers and other food items such as leaves of macrophytes, sand/mud and debris. So, as per this classification *Puntius sophore* falls in the category of euryphagic fish.

Das and Moitra (1956, 1963) divided fresh water fishes into three groups on the basis of ecological zone (niche) they occupy for feeding. These are surface feeders, mid or column feeders and bottom feeders. The feeding biology of *Crossocheilus latius latius* and *Garra gotyla gotyla* has been studied by Nath (1978, 1979), who reported their benthophagus habit. Saxena (1980) studied the feeding habit of *Labeo dero* and observed that inferior and slightly protrusible mouth showed bottom feeding nature of the fish as it takes its food from the mud. Bahuguna and Singh (1984) observed the surface feeding habit of hillstream species *Barilius vagra* and observed that this fish consumed both animal and plant food in about equal amount. Madhwal *et al.*, (1984) reported the herbivorous bottom feeding habit of *Schizothorax richardsonii*. Singh and Singh (2000) conducted their studies on feeding biology of *Labeo calbasu* and reported it to be detrivorous bottom feeder and stenophagous in nature on the basis of high percentage of organic detritus and a fair proportion of sand-mud in gut contents, fringed lips and shape of mouth. Dasgupta (2001) described herbivorous feeding habit of four *Labeo* species (*Labeo bata*, *L. calbasu*, *L. gonius* and *L. rohita*). Carnivorous feeding habit of *Horabagrus brachysoma* (Gunther) was observed by Kurian and Inasu (2001). Pandey (2001) observed carni-omnivorous feeding nature of *Clupisoma garua*.

During the present investigation it was observed that *Puntius sophore* feeds mainly on green matter. This fish takes sand-mud, debris along with other food items.

Since sand/mud, debris are found on the river bed and were observed in the gut in a very small proportion and only in few months of the year. This shows a column feeding tendency. The shape of the mouth also supports the present observation.

Feeding intensity refers to the degree of feeding as indicated by the relative fullness of the gut. It varies with the season, availability of preferred food items and is related with maturity stage of the fish and the spawning season of the species. Feeding intensity of fish have been studied by a number of seientists. Feeding and sexual maturity has a close relationship. Several investigators have been found that the feeding intensity of the mature fish decreased during the spawning season as compared to the other months of the year.

Hynes (1950) observed that feeding intensity increases with advancement of the maturity of fish. Rangarajan (1970) also observed a slackness in feeding during spawning season and activeness after spawning. Kothiyalingam (1970) studied the feeding intensity of *Grammoplites scaber* and found that the rate of feeding was very high in mature fishes, less in immature fishes and negligible in spawning and spent fishes. Sinha (1972) reported the lowest feeding intensity during pre-breeding period and maximum in post breeding period of fish *Puntius sarana*. According to Kapoor and Khanna (1994), there are certain constraints on feeding behavior of which an important is that a fish during reproductive state is most likely to stop feeding.

In the present study it was found that the feeding intensity decreased in prespawning and spawning months. During July the fish had peak spawning and hence does not prefer feeding. The feeding intensity increases after spawning (Table 3.5, Fig. 3.6) but during the spawning period stomach is either empty or only 1/4 full which may

be due to considerable increase in the size of the gonads and the fishes were in starvation so the food was found in very less amount. This observation also lends support to Karamchandani and Motwani (1955) and Lal and Dwivedi (1969) who reported that a predaceous bottom feeder *Rita rita* stops feeding just before spawning while it was highly active during maturation. The feeding intensity of the fish was also correlated with the availability of the food items in the environment (Jyoti and Malhotra, 1975 and Bahuguna and Singh, 1981). In the present case a decrease in feeding intensity during August - September may be attributed to non - availability of food items in the flooded river. It was observed that feeding intensity increased after spawning and became maximum in winter season (Table 3.5, Fig. 3.6).

Various authors have studied relative length of gut (RLG) as an indicator of its feeding behavior. Khanna (1961), Khanna and Pant (1964) and Varigina and Medani (1968) also worked on relative length of gut and correlated it to the food of fish. Singh and Bahuguna (1983a) studied the feeding behavior and morphology of gut of *Noemacheilus montanus* and found that the fish was carni-omnivore with short intestine. In *Garra gotyla gotyla*, which is a herbivorous fish, the length of gut was about eight times more than the body length (Dhasmana, 1990).Lange (1962) stated that variation in gut length is due to increase in in-digestable matter in the diet. Singh and Bahuguna (1983b) studied the feeding habit and gross morphology of alimentary canal of *Puntius chillinoides* (McClelland) and reported that fish is a herbivorous, column feeder and relative length of gut depends on sax and size of fish.

It is evident that RLG value has a close relationship with the nature of food of fishes, in herbivorous bishes such as *Labeo rohita, L. gonius* (Das and Moitra, 1956; 1958; 1963) and *L. dero*

(Das and Nath, 1965) the RLG values were 12.0, 9.5 and 8.9 respectively. In omnivorous fishes such as *Puntius conchonius, Barbus hexastichus* the RLG values were 3.3, 2.3 respectively (Das and Nath, 1965). In carnivorous fishes the RLG values were the lowest, e.g., *Bagarius bagarius* had 0.8 and *Notopterus chitala* had 0.4 (Das and Moitra, 1956). In the present study Relative length of gut (RLG) values ranged from 1.72 to 3.02 (Table 3.4). The RLG values determined for *Puntius sophore* falls in the category of omnivorous fishes. The RLG values depends on the size and availability of food items. The Relative length of gut (RLG) too pin points towards the omnivorous nature of this fish.

Seasonal variation in the gut contents have also been observed with the help of Gastrosomatic index (GaSI) by several workers. In the present study this index was calculated for each fish and finally an average value was taken into consideration. Gastrosomatic index shows seasonal variation in this species. It was observes that this index was high during winters with a peak in January (3.59) and lowest during monsoon (Table 3.4). The availability of food may be a reason for high feeding during winter months. Less feeding in monsoon might be due to spawning because physiological stress adversely affect the feeding of fish and the disturbed environmental conditions during monsoon may be another reason for low feeding. The value of GaSI in the present study varied from 0.209 to 3.59.

Afser (1990) reported Gastrosomatic index fluctuating from 1.342 to 7.239. Negi (1998) also repoted close fluctuation of GaSI from 0.35 to 3.15 in *Crossocheilus latius latius*. Sunder *et al.*, (1972) observed peak GaSI value in October and lowest in July in *Schizothorax niger*. Mishra (1982) reported the maximum GaSI value in December for *Schizothorax richardsonii* and minimum in June. Singh and Singh (2000) reported the

maximum GaSI value in November and lowest in the breeding season for *Labeo calbasu*. During the course of present study this index was calculated maximum during postspawning periods and minimum during prespawning and spawning months.

A 'selective mechanism' of feeding in fishes have been reported by various authors. According to Allen (1941), selective mechanism is the result of particular behavior of the fish and the availability of food is entirely dependent on the environment. Toor (1964) observed seasonal fluctuations in the food and reported a selective feeding in *Lethrinus lentjan* when both plant and animal food were available. Somasekharan (1979) reported that there exists a direct correlation between the availability of food organisms in the envioronment and their occurrence in the gut. Jyoti (1976) while studying the food and feeding habits of *Crossocheilus latius deplochileus*, *Schizothorax niger* and *Botia birdi* from the Dal lake (Kashmir) reported that these fishes are selective in their feeding habit. He concluded that *S. niger* feeds more or less constantly throughout the year and the greater occurrence of macrophytes in stomach of fish showed its choice for this food material. He also reported that zooplankton formed the main food (more than 50%) in the month of October and November and therefore, concluded that the fish was mixed feeder, i.e., herbi-omnivorous.

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During the present investigation, too much variation was observed in the percentage of different food items of *Puntius sophore*. The total percentage of plant matter and animal matter during winter, summer and monsoon season was 86.9/13.1, 64.3 / 35.7 and 36.5 / 63.5 respectively. The annual average 62.5 and 37.5 respectively. Thus the data indicates that this fish consumes more plant food than animal food. However, the consumption of animal matter during monsoon was more (64.3) and could

be attributed to non-availability of plant matter during monsoon months. Since the availability of food items varies in nature, the fish feeds on the available food items only. Hence, this fish consumes much larger amount of plant matter than animal matter and may be considered as herbi-omnivore. The RLG value also supports the present findings.

Thus it may be concluded that *Puntius sophore* (Ham.) inhabiting the Ganga river system at Allahabad is herbi-omnivore, column feeder and euryphagus in nature. Its feeding intensity was recorded maximum during winter and quite low during breeding season.

Table 3.1 : Monthly variation in the percental value of different food items of *Puntius sophore* during the year 2001 - 2002

	PLANT MATTER (%)			*ANIMAL MATTER (%)*			
nths	***Semi-digested Unidentified green matter***	***Diatom***	***Algae***	***Insects and their larvae***	***Crustaceans and their larvae***	***Rotifers***	***Miscellaneous***
lov	14.8	9.5	40.0	18.0	4.7	1.0	12.0
)ec	12.6	7.2	73.8	-	-	-	6.4
an	11.5	3.7	79.5	-	-	-	5.3
'eb	12.8	7.2	51.0	13.7	10.5	0.2	4.6
arch	33.3	4.2	29.0	13.4	7.9	0.4	11.8
pril	41.8	7.3	7.1	24.6	13.8	0.9	4.5
lay	57.1	7.8	-	15.0	13.0	0.8	6.3
ıne	26.0	8.4	14.8	22.3	19.0	1.2	8.3
uly	13.4	5.5	8.9	27.6	26.5	1.2	16.9
.ug	21.5	5.0	-	25.8	18.9	1.0	27.8
ept	26.9	2.8	-	24.9	23.8	0.6	21.0
Oct	23.5	6.6	-	25.3	20.5	1.5	22.6
ınual erage	24.6 ± 13.889	6.26 ± 2.03	25.34 ± 29.311	17.55 ± 9.58	13.22 ± 8.868	0.733± 0.494	12.29 ± s7.974

Table 3.2 : Seasonal variations in the percental value of different food items of *Puntius sophore*

	PLANT MATTER (%)			*ANIMAL MATTER (%)*			
Seasons	*Semi-digested Unidentified green matter*	*Diatom*	*Algae*	*Insects and their larvae*	*Crustaceans and their larvae*	*Rotifers*	*Miscellaneous*
Winter (Nov. – Feb.)	12.9	6.9	61.1	7.9	3.8	0.4	7.0
Summer (Mar. - June	39.6	6.9	12.7	18.8	13.2	0.8	8.0
Monsoon (July – Oct.)	21.3	4.9	2.2	25.9	22.4	1.1	22.
Annual average	24.6 ± 13.65	6.23 ± 1.154	25.33 ± 31.41	17.53 ± 9.06	13.13 ± 9.3	0.76± 0.35	12.4 ± 8.5

Table 3.3 : Seasonal variations in the percental value of plant and animal matter of *Puntius sophore*

Season	*Plant matter (%)*	*Animal matter (%)*
Winter (Nov. - Feb.)	86.9	13.1
Summer (May - June)	64.3	35.7
Monsoon (July - Oct.)	36.5	63.5
Average	62.5	37.5

Table 3.4: RLG and GaSI values of *Puntius sophore*

Month	*No. of fishes examined*	*RLG*	*GaSI*
November	25	2.21±0.258	1.65±0.439
December	30	2.33±0.089	2.72±0.325
January	33	3.027±0.223	3.59±0.735
February	34	2.525±0.274	2.332±0.7188
March	35	2.25±0.224	1.65±0.608
April	25	2.18±0.217	1.485±0.54
May	25	2.05±0.086	1.025±0.244
June	23	1.995±0.213	0.771±0.208
July	25	1.928±0.118	0.491±0.399
August	25	1.72±0.166	0.209±0.246
September	30	2.02±0.127	0.604±0.218
October	25	2.114±0.101	0.909±0.281

Table 3.5 : Feeding intensity and its index in *Puntius sophere*

S.No	*Months*	*Total no. of fish examined*	*Full*	*¾ full*	*½ full*	*¼ full*	*Empty*	*Feeding index*
1	Nov	25	4	9	6	5	1	52.0
2	Dec	30	8	10	6	5	1	60.0
3	Jan	33	19	5	5	4	-	72.7
4.	Feb	34	6	10	12	6	-	47.0
5	Mar.	35	5	10	13	5	2	42.8
6	April	25	6	4	6	5	4	40.0
7	May	25	3	6	8	6	3	36.0
8	June	23	3	4	7	7	2	30.4
9	July	25	-	4	-	10	11	16.0
10	Aug	25	-	2	2	6	15	8.0
11	Sept	30	2	6	8	13	3	20.0
12	Oct.	25	7	3	8	5	2	40.0

Fig 3.1: Monthly variation in the percental value of different food items of Puntius sophore during the year 2002.

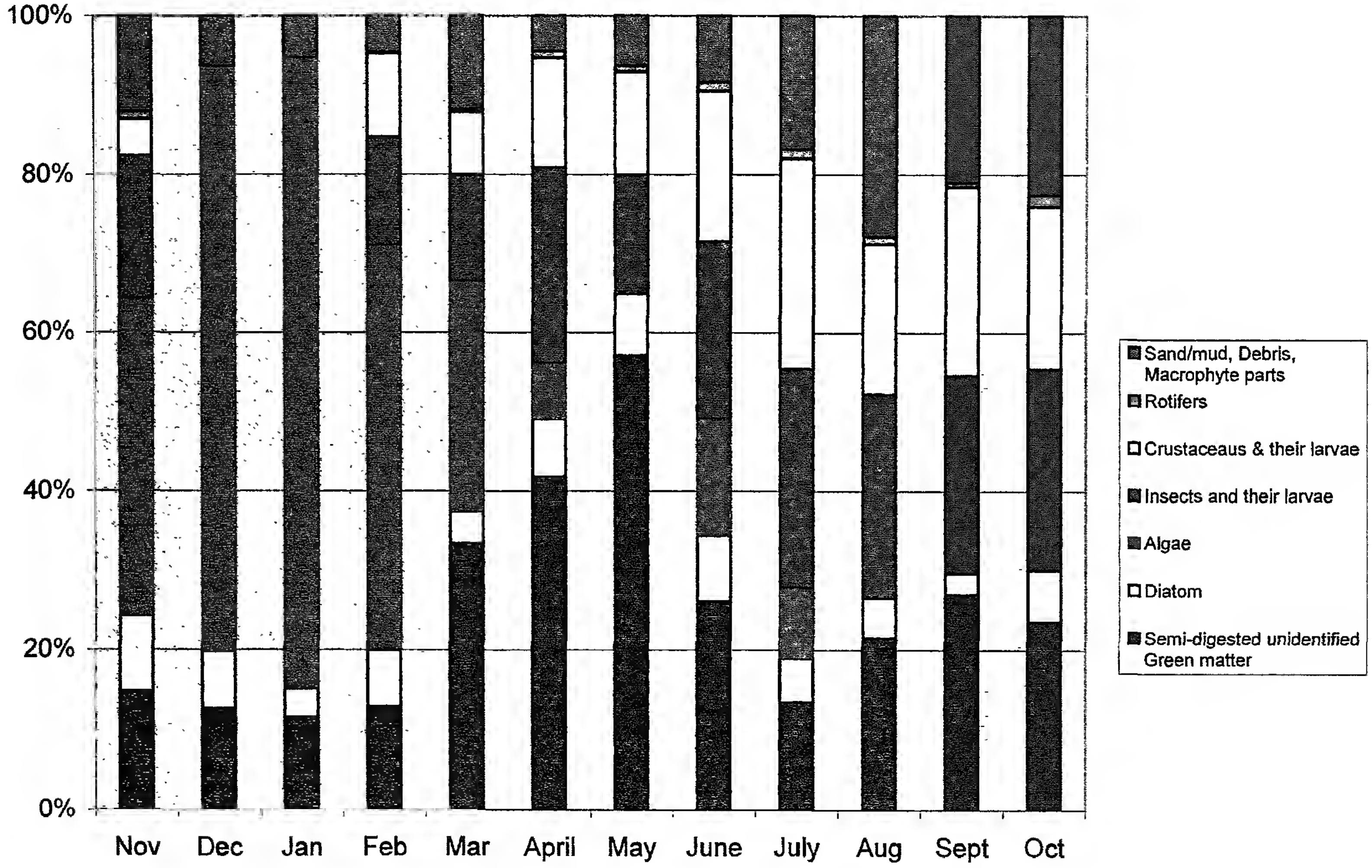
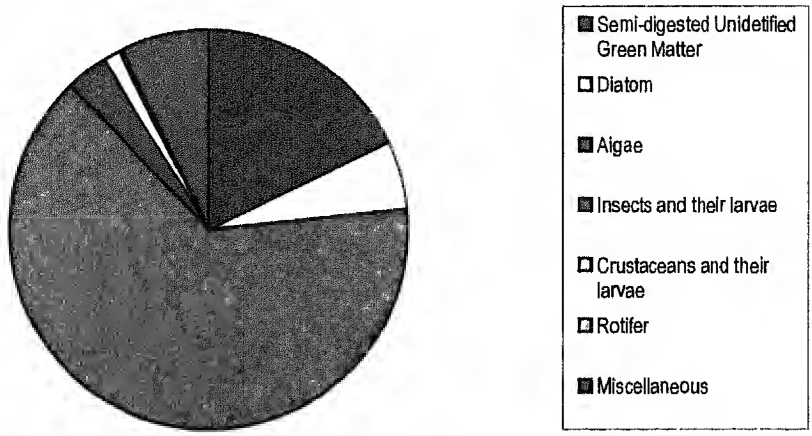
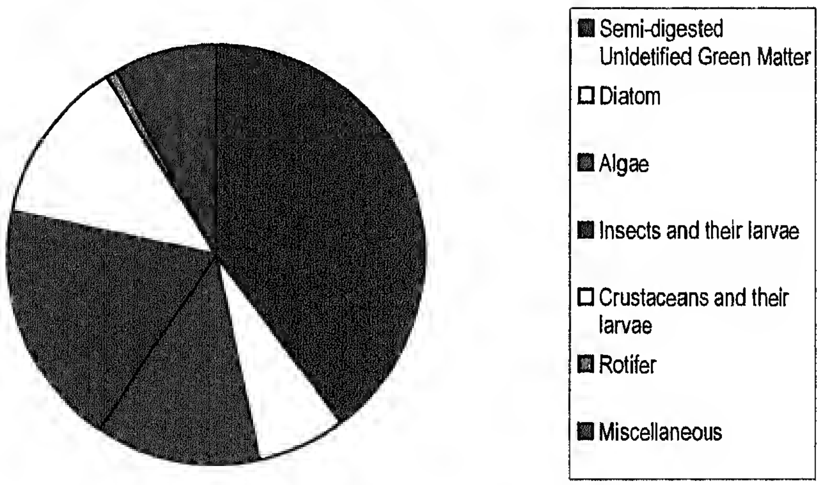


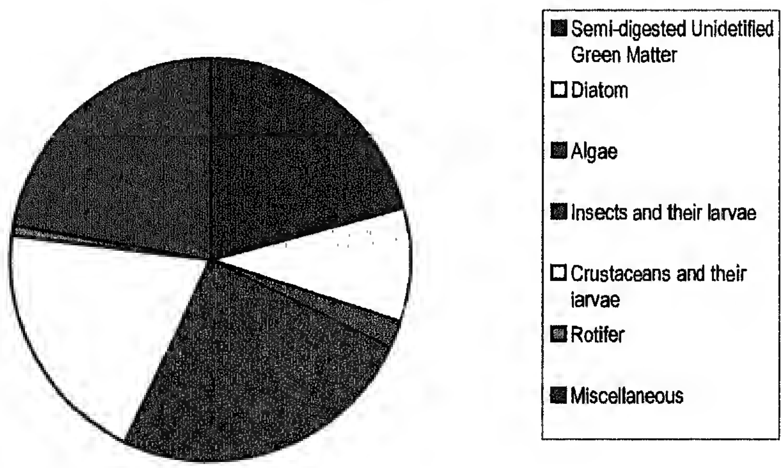
Fig 3.2 Seasonal variation in the major food items of *P. sophore* .



WINTER SEASON



SUMMER SEASON



MONSOON SEASON

Fig 3.3 Seasonal variation in the percental value of animal and plant matter *of P. sophore* during the year 2001-2002.

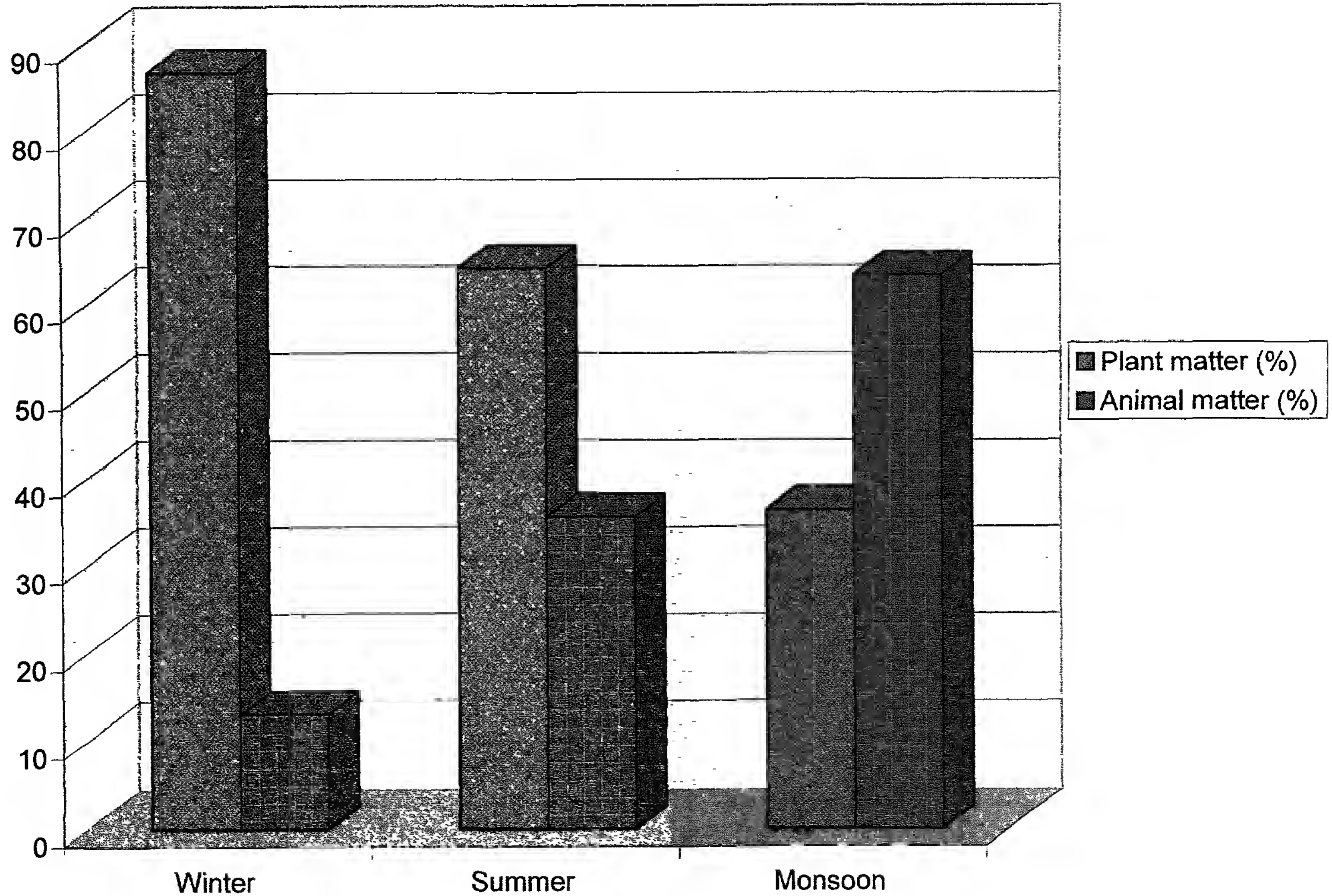


Fig. 3.4: Variation in GaSI values of *P. sophore*

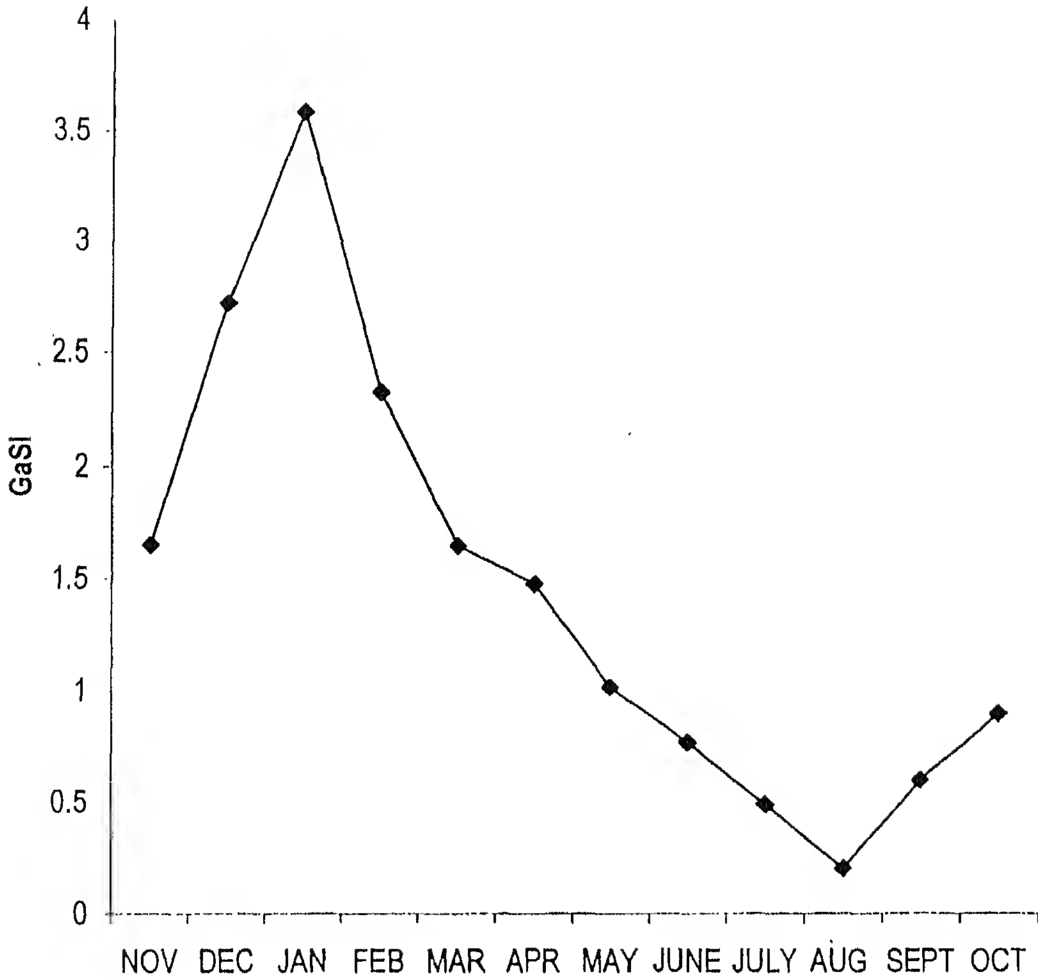


Fig 3.5: RLG values of *P. sophore* during different months

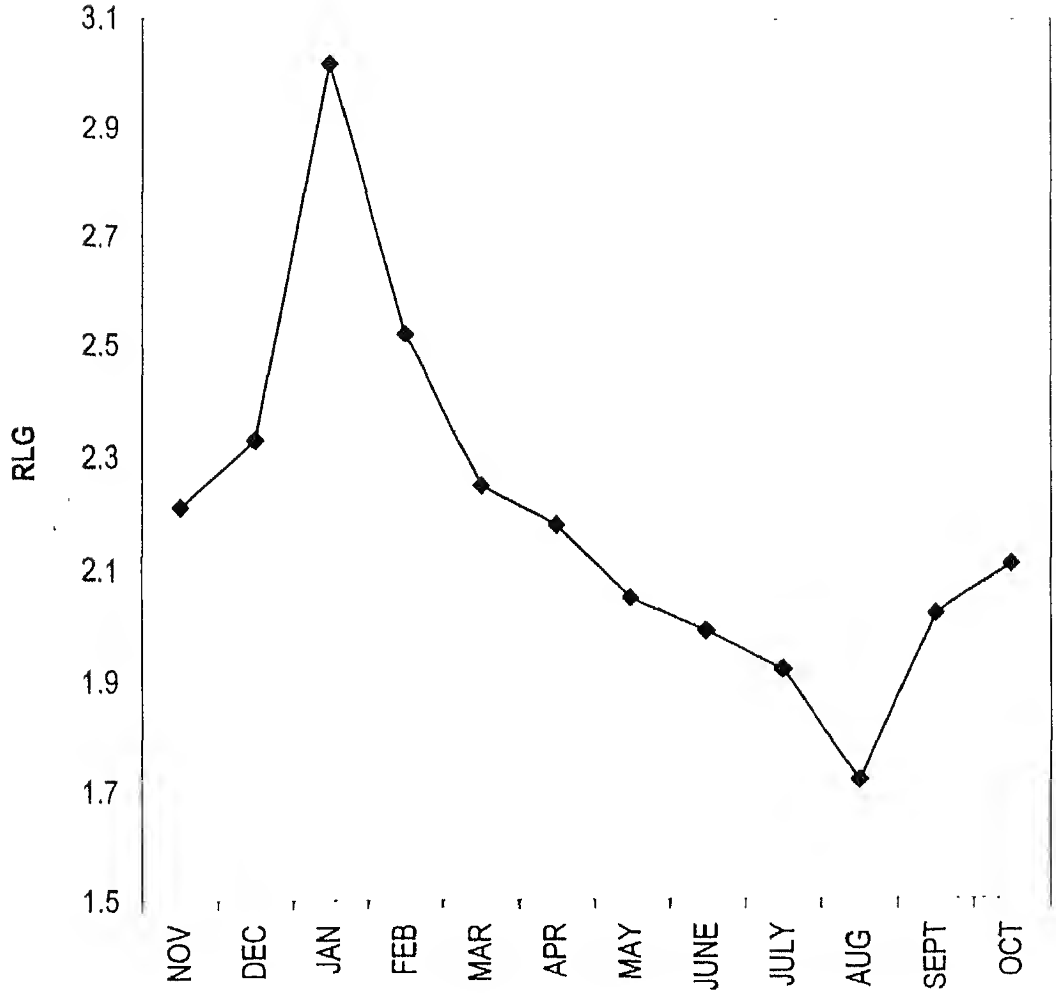
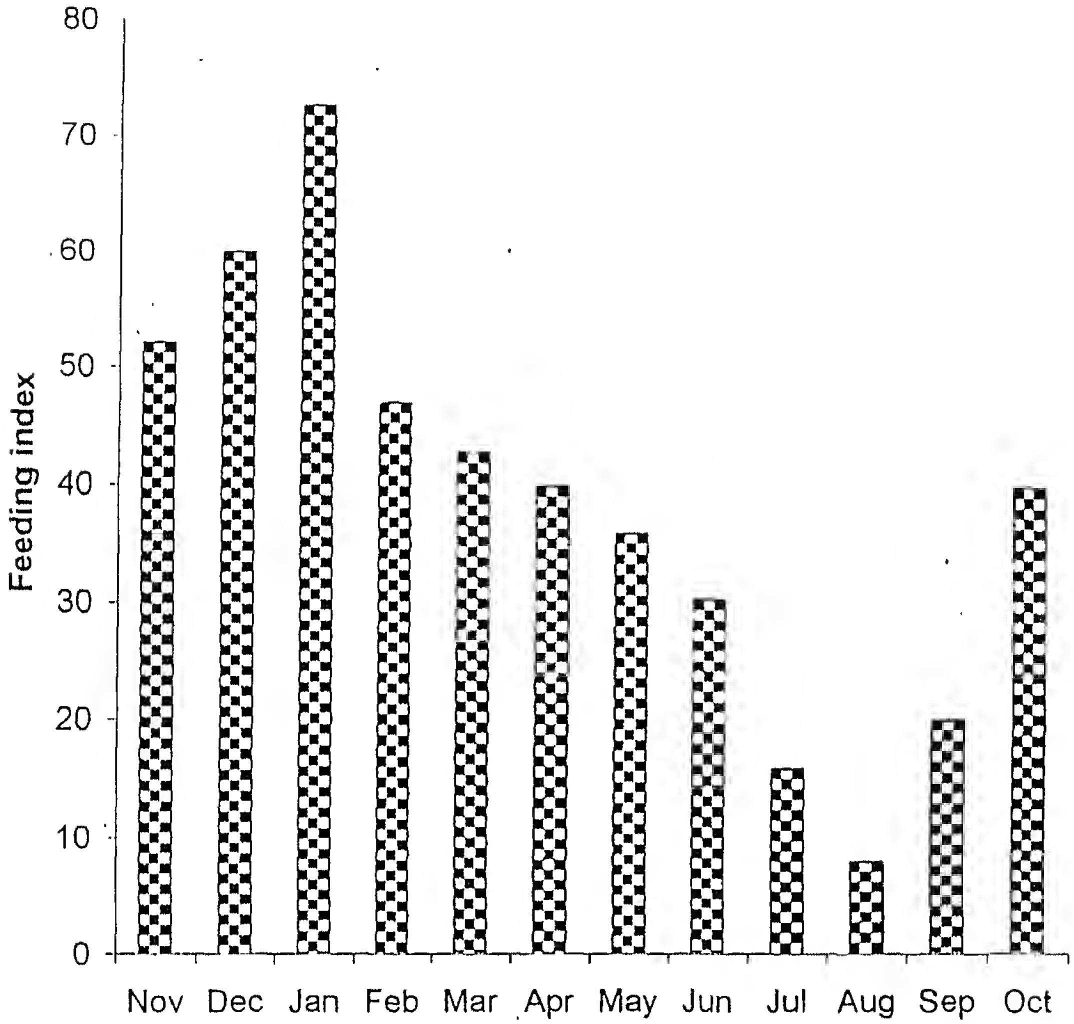


Fig 3.6: Monthly variatin in feeding index of *P. sophore*



CHAPTER VI

BREEDING BIOLOGY

BREEDING BIOLOGY

(A) Maturation and Spawning

INTRODUCTION

Maturation and spawning are the two different aspects of breeding. Fish generally exhibit seasonal changes in the gonads (testes and ovaries) leading to the production of gametes. The term 'maturity' is used for expressing the attainment of the reproductive capacity of an individual and 'maturation' is the period prior to the maturity when an individual undergoes morphological changes reflected by gonads. Similarly spawning is the act of laying the spawns, i.e., sperm and ova which leads to fertilization (Qasim, 1973). Each species spawns during a specified period under favorable conditions. The part of the year during which the gonads attain full maturity sand spawning occurs in the population is called 'breeding season' of the species.

Determination of maturity stages, length at attainment of first sexual maturity and sex - ratio are some of the important parameters to assess the status of any fish stock. Fish culture techniques can be improved if detailed knowledge regardingthe reproductive biology of the species is thoroughly investigated and seasonal rhythms are well understood.

Various attempts has been made to study the reproductive biology of fishes by Hijort (1911), Keisselvitch (1923), Graham (1924), Clark (1925), Bull (1928), Walfor (1932), Clark (1934), Hickling and Rutenberg (1936), Hickling (1940), Khan (1942), Hora (1945), Nikolsky (1950), Simpson (1951), June (1953), Lehman (1953), Yuen

(1955), Alikuni (1956), Prabhu (1956), Bagenal (1957), Sarojini (1957), Pillay (1958), David (1959), Qasim and Qayyum (1961), Swarup (1962), Natrajan and Jhingran (1963), Nikolsky (1963), Bhatnagar (1964), Das (1964), Mathur (1964), Saigal (1964), Antony Raja (1966),Chondar (1970, 1977), Bhatt (1971), Kulkarni (1971), Jyoti and Malhotra (1972), Parmeshwaran *et al.*, (1972), Devraj (1973), Desai (1973), Verghese (1973), Malhotra and Jyoti (1974), Thakur (1978), Mann and Mills (1979), James and Bargi (1980), Joshi and Khanna (1980), Prakash *et al.*, (1980), Chandrasom and DeSilva (1981), Desai *et al.*, (1981), Pathani (1981), Thakre and Bapat (1981), Singh *et al.*, (1982), Bowering (1983), Isola and Relini (1984), Nautiyal (1984), Singh *et al.*, (1985), Sinha (1985),Pokhriyal (1986), Khan (1986), Echeverna (1987), Dobriyal and Singh (1987), Agarwal *et al.*,(1988), Jakupsstovu (1988), De and Saigal (1989), Dobriyal and Singh (1989), Jabde (1990), Khan *et al.*,(1990), King (1991), Afser (1991), Beacham and Murray (1993), Pauly (1994), Iguchi and Yamaguchi (1994), Wootton (1994), Fonda (1995), Admassu (1996), Joshi and Sunder (1996),Stergion *et al.*,(1996), Tomasini *et al.*,(1996), Bhatt *et al.*,(1998), Devadoss (1998), Negi (1998), Rautela (1999), Dobriyal *et al.*,(2000), Pandey (2001), Kumar and Mishra (2001), Phukan (2002), Stark and Somerton (2002), Braccini and Chiaramaonte (2002), Watson and Smale (1998),Will and Reinert (2002), Oliva-Paterna *et al.*,(2002).

The reproductive biology of *Puntius sophore* from the riverine environment is not studied so far. Hence, the present attempt was made.

OBSERVATIONS

Maturity stages

On the basis of shape, size and colour of the ovary six maturity stages (Table 4.1) were observed in *Puntius sophore* with a slight modification in the ICES scale of Wood (1930).

Stage I (Immature) : The ovaries are small, thin, thread - like, translucent, pale or dirty white in colour. The ovaries occupy only a small part of the body cavity and ova were not visible to the naked eye.

Stage II (Maturing I) : The ovaries are thicker than that of the stage I. It becomes slightly larger, thicker, opaque and light yellowish in colour. There is an increase in the weight of ovary.

Stage III (Maturing II) : There is further increase in the weight of ovaries, which have a yellow colour and occupy about 1/2 of the body cavity. Large number of opaque eggs are visible to the naked eye.

Stage IV (Mature I) : The ovaries are further enlarged occupying 1/2 to 3/4 of the body cavity. They are turgid, yellow in colour and ova are visible to the naked eye through the thin ovarian wall.

Stage V (Mature II) : Ovaries are very much enlarged occupying the entire body cavity. The ovaries are turgid and yellow in colour and they attain their maximum size.

Stage VI (Spent) : The ovaries are flaccid, shrinked and sac-like, reduced in weight and have a dull colour.

Development of ova to maturity

The frequency polygon of ova diameter for various maturity stages are presented in fig. 4.1. The curves represent the average frequencies from the samples of specimens

representing the same stage of maturity. The graph indicated a gradual progression of the mean diameter from October - November (Stage I) to July - August (Stage V) are thereafter abruptly diminished in Stage VI which indicated termination of impregnated ova.

In Stage I, there is only one batch of immature ova with a mode at 5-20 omd with a peak at 5 omd. Ova below 5 omd (1 omd = 0.0156 mm) were not counted. In Stage II the ova diameter had increased with the mode shifted to 5-30 omd. As development progressed in Stage III, the first batch of ova was separated from the general egg stock with a mode shifted to 5-40 omd. This batch of egg continuously advanced and in Stage IV, the mode progressed to 10-50 omd with a peak at 50 omd. The diameter of fully mature ova (Stage V) ranged from 10-60 omd with a peak value of 60 omd. The maximum egg size was measured as 60 omd. The spent ovary (Stage VI) contained only degenerating ova.

In *Puntius sophore*, the maturity stages have clearly shown a protracted spawning which started from August and continued up to September.

Frequency of spawning :

The percentage occurrence of fish of various maturity stages (Table 4.2 and Fig. 4.2) showed that the fish of advanced maturity (Stage V) was observed in the month of July - August (87.5%) . The first appearance of spent fish was observed in August (12.5%), continuing till September (94.12%), giving a spawning season from August to September. The maximum number of immature fishes was observed in October which also supported the above observation.

Gonadosomatic Index (GSI) :

The gonadosomatic index was calculated for each fish of either sex and the monthly average values were calculated separately (Table 4.3). In females and males the maximum GSI values were recorded 12.075 and 1.849 respectively in the month of July (Figs. 4.3 and 4.4). The analysis of gonadosomatic index also supported one, short durational spawning of fish.

Size at first maturity

For determining the size at which *Puntius sophore* mature first, fish were grouped at 10 mm interval and the percentage of males and females maturity at each length unit has been depicted in Table 4.4 and 4.5 respectively. The percentage composition of mature fishes revealed that 50% level of the mature fish were of the length of 58 mm in case of males and 66 mm in females (Fig. 4.5)

(B) Fecundity and Sex ratio

INTRODUCTION

The fecundity of fish is an important aspect of fishery biology. The fecundity is the reproductive potential of fish in terms of egg production, which ensures the survival of the species under the condition in which it originated and exists. The knowledge of fecundity of fish is extremely important for the successful management and exploitation of its fishery. It also provides the replenishment so essential for the preservation of the species and its abundance. As per the analysis of fecundity data with size, age and weight of the fish has often been used to provide a reliable index of density dependent factors affecting the population size.

Fecundity may be defined as the number of ripening eggs in the ovaries of female prior to spawning. The knowledge of fecundity and its relationship with the body

measurements are considered very useful in fishery biology and fishery management. It gives information regarding the possible number of eggs and fry likely to be produced can be used for selecting the fish of high productivity for fish culture.

Fecundity, being a phylogenetic character of a fish is dependent on various environmental factors, which the fish may encounter in the different stages of its life history. The food consumed by the fish, especially the parent population, determines not only the fecundity but also the quality of the sexual products and the viability of the offspring (Nikolaev 1958, Nikolskii 1961 a and b). The number of eggs produced by a fish differ not only in different species but also in different races of the same species due to genetic differences, influenced by the environment and even the geographical distribution is known to influence the fecundity (Somavanshi, 1985). Similarly study of sex ratio in a population of the fish indicates about the deviation from the natural sex ratio 1:1

Studies on fecundity and sex ratio of fish have been made by Raitt (1933), Clark (1934), Hickling (1940), Simpson (1951), Lehman (1953, 1958), Alikunhi (1956), Bagenal (1957), McGreger (1957), Sarojini (1957, 1958), Kandler and Dutt (1958), Pillay (1958), Jhingran (1961), Pantulu (1963), Qasim and Qayyum (1963), Hodder (1963), Bhatnagar (1964, 1972), David (1963), Das (1964, 1967), Mathur (1964), Balon (1965), Gupta (1968), Chonder (1970, 1977), Parmeshwaran *et al.*, (1972), Devraj (1973), Desai (1973), Varghese (1973, 1976), Hanumantha Rao (1974), Malhotra and Jyoti (1974), Ramamohan Rao (1974), Dan (1977), Joshi and Khanna (1980), Chandrasoma and DeSilva (1981), Pathani (1981), Singh *et al.*, (1982), Nautiyal (1982), Dobriyal (1983), Pokhriyal (1986), Dobriyal and Singh (1987, 1989, 1993), Agarwal *et al.*, (1988),

Stergiou *et al.*,(1996), Dobriyal and Negi (1998), Watson and Smale (1998), Singh (1999), Routela (1999), Pandey (2001), Singh and Singh (2001), Biswas (2001), Will *et al.*,(2002), Oliva-Paterna *et al.*,(2002), Sinde *et al.*,(2002), Phukan and Biswas (2002), and Neethiselvan *et al.*,(2002).

The fecundity of *P. sophore* from the Allahabad region was not studied so far; hence the present attempt was made.

OBSERVATIONS

The fecundity of *P. sophore* ranged from 439 in the specimen measuring 52 mm and weighing 2 gm to 24385 in an individual measuring 116 mm and weighing 26 gm

Body relationships with fecundity

The following relationship between fecundity and body parameters were observed :

1. ***Fecundity and fish length*** :

   Table 4.6 gives the relationship between fecundity and total length of *P. sophore*. A straight line relationship was obtained (Fig. 4.6) on plotting the log of fecundity against the log of total length of fish. The following formula was established for this relationship (Table 4.9):

   $$Log\ F = 6.5676 + 5.3349\ FL \qquad (r = 0.91047)$$

   Where F = fecundity and FL = fish length

2. ***Fecundity and fish weight*** :

   The relationship between fecundity and fish weight is shown in Table 4.7. The log values of fecundity and fish weight showed a straight line (Fig.4.7). The relationship according to standard formula was obtained as follows :

   $$Log\ F = 1.96278 + 1.7789\ FW \qquad (r = 0.88959)$$

Where, FW = fish weight

3. *Fecundity and ovary length* :

The log values of ovary length and fecundity (Fig. 4.8) showed that the relationship between these two variables is also of a linear form.

$$Log\ F = -0.0888 + 2.64815\ OL\ (r = 0.73668)$$

Where, OL = ovary length

4 *Fecundity and ovary weight* :

The relationship between ovary weight and fecundity (Fig. 4.9) was found to be much closer than any relationship. A linear relationship between these two parameters was expressed as :

$$F = 3.6818 + 1.1089\ OW \qquad (r = 0.954792)$$

Where OW = ovary weight

The analysis of variance ('F' test) was conducted to find out the degree of relationship between fecundity and fish length, fish weight, ovary length and ovary weight. The F-test shows that for all the relationships the value of 'F' was high and significant at 1% level (Table 4.8)

Relative fecundity

Relative fecundity was expressed as fecundity per gram body weight of fish . In the present case it varies from 194 to 938. It was found in increasing order with the increase of fish weight and ovary weight.

Sex ratio

The sex composition in *Puntius sophore* is shown in table 4.10. A total of 605 specimen were examined, out of which 211 males (34.9%) and 394 (65.1%) were females. The number of males and females differ significantly ($\chi^2 = 55.35$) with their mean ratio 1:1.86

DISCUSSION

The study of breeding biology, an important branch of fishery science, is useful in several applies aspects of fishery, including its management . Breeding ensures the continuation of the species. The development and improvement of fisheries in an area depends upon the knowledge of biology of local fishes. It is known that success or failure of any fishery is largely dependent on the reproductive potential of the concerned species.

Fish spawning is the process by which any species reproduces successfully in a fluctuating environment and thereby maintains viable populations. Several authors (Qasim and Qayyum, 1961; Parmeshwaran *et al.*, 1972) have stated that the breeding season of different freshwater fishes varies in time and space. Even the time of breeding of the same species has been reported to alter under various ecological conditions. Many fishes have a yearly cycle of spawning and once they have begun it, they follow it until they die. Several other species spawn more than once in a year and more or less continually. Qasim and Qayyum (1962) were of the opinion that in any body of water, the success or failure of a species largely depends on its spawning potential.

Various types of spawning tendencies of fishes can be studied from the development of intraovarian eggs. Deshmukh (1973) in *Pamadasys hasta* (Bloch) observed the spawning periodicity on the basis of intraovarian eggs in the ripe ovaries and reported that fish spawned only once in a year with a restricted short period of spawning. Clark, 1925, 1934; Hickling and Rutenberg, 1936 stated that the differences in

the spawning behaviour of teleost can to a certain extent be ilustrated on the basis of condition revealed by the unspawned egg in the ovary. In the former case the batch of transparent, yolkless, small eggs destined to mature will be withdrawn from the egg stock in a single group, while in the latter case, the withdrawal of eggs from the egg stock, to undergo maturation will be a continuous process, there will be no separation between the general egg stock and the maturing eggs.

Several workers (Kisselvitch, 1923; Walfer, 1932; Clark, 1934; Prabhu, 1956; Bagenal, 1971; Bhatnagar, 1972; Southward and Demir, 1974; Hislop, 1975; Pathak and Jhingran, 1977; Ware, 1977; DeMartini and Fountain, 1981; Khan, 1986; Imai and Tanaka, 1987; Dobriyal and Singh, 1987, 1989; Khan *et al.,* 1990; Iguchi and Yamaguchi, 1994; Bhatt *et al.*, 1998; Pandey, 2001; Sivakami *et al.,* 2001; Phukan and Biswas, 2002) have studied the spawning behavior of fishes on the basis of size distribution of ova in the ovaries.

During the present investigation on the basis of detailed study of intra-ovarian eggs of the female fish under study, six maturity stages were classified. These are Immature, Maturing I, Maturing II, Mature I, Mature II, Spent (Table 4.1). Jhingran (1961) in *Setipinna phasa*, Lal (1970)in *Rita rita*, Dobriyal and Singh (1987) in *Barilius bendelisis*, Afser (1991) in *Clupisoma garua*, Pandey (2001) in *Clupisoma garua*, Sivakami *et al.*, (2001) in *Priacanthus hamrur* described seven maturity stages. However, less than seven maturity stages have been also observed by a number of workers. Prabhu (1956) observed four stages of maturity namely immature, maturing, mature and ripe in *Therapon jarbua, Macrones vittatus* and *Chirocentrus dorab.* Qasim and Qayyum (1961) conducted their studies on breeding habits of carps, catfishes,

murrels, grey mullet and spiny eel and reported five maturity stages. Rangarajan (1971) found five maturity stages *viz.*, immature, maturing, early and late mature and ripe in *Lutianus Kamira*. Sunder *et al.*, (1979) in *Schizothorax niger* also described five sexual maturity stages. Deshmukh (1973), Natrajan and Reddy (1980), Somavanshi (1980), Dobriyal and Singh (1987) adopted ICES scale (Wood, 1930) for the classification of maturity stages. Nautiyal and Lal (1985) have adopted a four stage maturity scale with slight modification given by Qasim (1973). Pokhrital (1986) found only one immature satge in *Crossocheilus latius latius* (Ham.). In *Glyptothorax pectinopterus* and *G. madraspatanum* Dobriyal and Singh (1989, 1993) combined first and second stages of maturity into one stage. Six maturity stages, immature, maturing, developing, late developing, ripe and spent observed by Phukan and Biswas (2002) in *Erethistes pussilus*. Neethsilvan *et al.*,(2002) observed four maturity stages in *Sepiella inermis*. Starck and Somerton (2002) also found five maturity stages *viz.*, immature, mature developing, mature gravid, mature spawning and mature spent. It has been shown by various workers that monthly measurement of ova diameter may also help to determine the spawning seasons and frequency of spawning as it gives the idea about the ripening of eggs. Clark, 1934; Prabhu, 1956; Pillay, 1958; Rao and Rao, 1972; Bhatnagar, 1972; Luther, 1973; Pathak and Jhingran, 1977; James and Bargi, 1980; Nautiyal, 1984; Khan, 1986; Dobriyal and Singh, 1989 have reported spawning season in fishes by ova diameter measurements.

According to Hickling and Rutenberg (1936), ova diameter measurements in the mature ovaries may give an evidence of the duration of spawning in a fish whether spawning is short and definite or prolonged and indefinite. In *Sardinella longiceps* Antony Raja (1966) and in *Notopterus notopterus* Parmeshwaran and Sinha (1966)

observed a constant ratio between the ova of different diameter range during the breeding season and rejected the possibility of multiple spawning. In *Tachysurus dussumieri* Vasudevappa and James (1980) reported that the ovary consists of mature, maturing and immature stocks of ova and mature group were distinctly separated from maturing group of ova and on this basis they concluded that fish spawns once in a year for a short duration. Dobriyal and Singh (1987), in *Barilius bendelisis*, on the basis of ova diameter measurements, observed intermittent breeding.

Various attempts have been made by different workers to study the spawning periodicity and spawning season of the fish. Prabhu (1956) in *Therapon jarbua*, *Macrones vittatus* and *Chirocentrus dorab*, Antony Raja (1966) in *Sardinella longiceps*, Parmeshwaran and sinha (1966) in *Notopterus notopterus*, Deshmukh (1973) in *Pamadasys hasta* (Bloch), Badola (1979) in *Noemacheilus sp.*, Pokhriyal (1986) in *Crossocheilus latius latius*, Dobriyal and Singh (1989, 1993) in *Glyptothorax pectinopterus* and *G. madraspatanum*. Phukan and Biswas (2002) in *Erethistes pussilus* have observed a single, restricted and short period of spawning.

Jhingran (1961) and Desai (1973) observed multiple spawning in *Setipinna phasa* and *Tor tor* during breeding season. Bhatnagar (1964) reported that *Tor putitora* from Bhakra reservoir spawns intermittently throughout the major part of the year. Dobriyal and Singh (1987) reported intermittent breeding of *Barilius bendelisis* on the basis of ova diameter measurements and GSI values. Sivakami *et al.*, (2001) in *Priacanthus hamrur* found that this fish breed during April to July, shedding two batches of ova. Oliva-Paterna *et al.*, (2002) in *Cobitis Paludica* observed multiple spawning that releases a minimum of two batches of eggs per female each year.

A number of workers like Pillay (1958) in Hilsa, Swarup (1959) and Mathur (1964) for Hilsa in Ganga, Jhingran (1961) for *Setipinna phasa*, Bhanagar (1964) in *Tor putitora*, *Cyprinus carpio*, *Mystus seenghala* and *Schizothorax plagiostomus*, Desai (1973) in *Tor tor*, Dobriyal and Singh (1987) in *Barilius bendelisis*, Demeko Admassu (1996) in *Tilapia* (*Oreochranis niloticus*), Yap (1980) in *Osteochilus hasselti*, Khan *et al.*, (1990) in *Mystus nemurus*, Joyeux *et al.*, (1991) in *Gobius lager*, Tomasini *et al.*, ((1991) in *Syngnathus abaster*, Ruchnon *et al.*, (1993) in *Lipophrys pavo*, Neethsilvan *et al.*, (2002) in *Sepiella inermis* have reported multiple and prolonged spawning. According to Nikolsky (1969), prolonged breeding season is generally characteristic of repeat spawners.

During the course of present study it was observed that *Puntius sophore* spawned for a limited period during August to September. The ova diameter frequency polygons of different maturity stages shows the continuous development of oocyte in different maturity stages. In the mature ovary mainly two types of ova was found. The mature ova formed only one batch which is sharply differentiated from immature stock which indicated that only one batch of ova would be released during the spawning period, while the other batch of immature ova did not mature in the same year. This indicated that *Puntius sophore* breed only once in a year with only one batch of ova and its spawning season was restricted to a short duration. During spawning and postspawning periods the ovary contained few fully ripe unspawned oocyte together with immature oocyte undergoing atresia. Jobling (1996) suggested that if suitable conditions are not found than the eggs may become atresic, degenerate and ultimately resorbed in the body.

The prediction of frequency and season of spawning by occurrence of mature fish is a widely accepted method. Kesteven and Toor (1964) ascertained the maturity and spawning season of fish on the basis of appearance of ripe and spent fishes. This has been observed on the basis of percentage occurrence of the fish of different maturity stages in different months. In the present study spawning season was also ascertained by recording the percentage occurrence of gonads in various maturity stages every month. The fish of advanced maturity were observed in the month of July (87.5%) and August (87.5%). The first appearance of spent fish was observed during August (12.5%) and September (94.12%). This indicated that spawning season of fish was between July and September. In October 100% immature fish were observed (Table 4.2).

Since the occurrence of ripe gonads were more during July and August with higher incidence of spent ones from August and September, it may be concluded that *Puntius sophore* has a short spawning season (August - Sept.) shedding only one batch of ova. This observation also confirms the spawning season of this fish between July to September.

Monthly determination of Gonadosomatic index has significant role in the life of fishes as well as it is helpful in fish breeding too. Gonadosomatic index (GSI) of the fish increases with the maturation of fish, being maximum during the peak period of maturity and declining abruptly after spawning. The Gonadosomatic index (GSI) has been employed to indicate the maturity and periodicity of spawning and for predicting the spawning season of fishes by number of workers (Bhatt, 1968; Parmeshwaran *et al.*, 1974; Sobhana and Nair, 1974; Natrajan and Reddy, 1980; Nautiyal, 1984; Khan, 1986;

Tomasini *et al.*,1996; Dobriyal and Singh,1987, 1989, 1993; Singh, 1999; Sivakami *et al.*,2001; Kumar and Mishra, 2001; Neethiselvan, 2002; Phukan and Biswas, 2002.

In the present study the Gonadosomatic index has been calculated for both sexes of *Puntius sophore* separately (Table 4.3). It showed an increasing trend from October onwards in both male and female fish and the peak value was found during July when the oocytes was fully matured and was ready to shed the eggs (fig. 4.3). In July the maximum value of GSI was calculated 1.849 for male and 12.075 for female. Gradual shedding started from the month of August to September, hence the GSI have decreased gradually and remained low till September showing the termination of breeding. The minimum value of GSI was recorded in the month of October 0.299 for male and 0.486 for female (Table 4.3). This clearly indicates that the spawning is over and only spent fishes were present in the catch. In the resting stage (October - November) the value showed slight increase and remained increasing till its peak during July. The peak of GSI value indicated the spawning periodicity in fishes. The gonadosomatic index is an indicator of fish spawning in temperate and tropical region (Bouain and Sian, 1983; Biswas *et al.*, 1984; Sinovcic, 2000)

Further it was found that *Puntius sophore* spawns only once in a year and spawning period was short and restricted, extending from July to September. This is strictly supported by the ova diameter frequency distribution and the occurrence of the ripe specimens.

The size at first maturity of male and female *Puntius sophore* was determined graphically by tabulation of percentage occurrence of mature fish during spawning season. The 50% level in the maturity, which has been taken to represent the mean length

at which the maturity was obtained were 58 mm and 66 mm for male and female *Puntius sophore* respectively (Fig. 4.5). This shows that male matures earlier (58 mm) than female (66 mm).

The size at first maturity has an important role in understanding the life history of a species during its evolution and gives a rough estimate of the ultimate size of the species (Biswas, 2001). According to Kesteven (1960), this indicates the level at which protection should be operated for being fished and every fish should be given an opportunity to spawn once or twice at least in its life time. Several workers have also determined the size at first maturity in different fish species. Sarojini (1957) in *Mugil persia*, Pillay (1958) in *Hilsa*, Desai (1972) in *Opisthoptenes tardoore*, Vasudevappa and James (1980) in *Tachysurus dussumieri*, Natrajan and Reddy (1980) in *Liza dussumieri*, Chandrasoma and DeSilva (1981) for *Puntius sarana*, Bahuguna (1991) for *B. barna*, Dobriyal and Singh (1993) for *G. madraspatanum*, Pandey (2001) in *Clupisoma garua*, Sivakami *et al.*,(2001) in *Priacanthus hamrer*, Phukan and Biswas (2002) in *Erethistes pussilus*, Neethiselvan (2002) in *Sepiella inermis*, Stark and Somerton (2002) in *Lepiopselta bilineata*.

Fecundity is a measure of reproductive capacity of a female fish and can be defined as the total number of ripe eggs per brood prior to the next spawning season. Fecundity studies are essential for estimating the size of the spawning population of a species. The knowledge of the fecundity of spawners of different ages, along with length and weight can provide the basic information from which change in total egg production can be determined. Fecundity finds application in fish taxonomy (racial studies) on the one hand and in fishery biology (population studies) on the other hand. It is also used in

estimating abundance of female population. Fecundity can also be used as a parameter of environmental suitability of the fish (Simpson, 1951; Khasem, 1968; Nikolsky, 1963;). A continuous deterioration of the environment produces qualitative and quantitative changes in the ecosystem, on account of these, fishes become smaller in size and attain earlier maturity.

Several investigators have studied the fecundity of a number of fishes. Hanumantha Rao (1974) studied the fecundity of a major carp *Cirrhinus mrigala* and reported it to vary from 75,400 to 11,23,200 for the fish 349-810 mm in length. Joshi and Khanna (1980) found the fecundity of *Labeo gonius* of 270-490 mm length to vary between 45,168 to 3,80,714. In the same species, Chondar (1970) found the values between 2,73,955 and 5,39,168 in the fish of same length. In *Puntius chilinoides*, Singh *et al.*, (1982) observed the fecundity ranging from 2,097 to 7,978 for the fishes between 130 to 220 mm. Bhatnagar (1964) reported fecundity of *Labeo dero* from 67,288 to 7,10,934 for the fish measuring 330 mm to 504 mm in total length and for *L. bata* 30, 1, 861 to 5,76,251 in the fish of 441 to 544 mm. Fecundity of *Tor tor* was found to be 30,400 for 625 mm fish by Karamchadani *et al.*, (1967). Desai (1973) reported 42,600 fecundity for the same fish measuring 687 mm . Dobriyal (1986) observed this to be 1.213 lac in *Labeo rohita* and 3.29 lac for *Catla catla* through induced breeding. Dobriyal and Singh (1987) reported fecundity range from 900 to 5048 for *Barilius bendelisis* and 1710 to 8050 for *Glyptothorax pectinopterus* was also reported by Dobriyal and Singh (1989). Agarwal *et al.*, (1988) studied the fecundity of *Noemacheilus montanus* from 380 to 1746. Singh and Singh (2001) observed fecundity range from 1.3 to 5.07 lacs in a total length range of 30.0 to 60.0 cm in *Labeo calbasu*. Pandey (2001) found it to vary from 12,620 to 21,470

for the lowest size group (29.2 to 32.6 cm) and 80,120 to 1,24,650 for the highest size groups (40.4 to 44.3 cm). In *Erethistes pussilus* Phukan and Biswas (2002) reported that fecundity varied between 220 to 1672. In the present study the fecundity of *Puntius sophore* was found to vary between 439 to 24385 for the fishes of 52 to 116 mm (Table 4.6).

During the present study, four linear relationship of fecundity with body parameters like fish length, fish weight, ovary length and ovary weight of *P. sophore* were observed. The result revealed that the fecundity was more closely related to fish length (r=0.9147) than fish weight (r=0.8895) as also reported by Joshi and Khanna, 1980 in *Labeo gonius*. In *Labeo calbasu*, the fecundity is related more to the weight of ovary (Singh and Singh 2001). Pandey (2001) observed that fecundity was more related to the weight of ovary. In *P. sophore* also there is an increase in the number of ova produced with the increase in weight of ovary. The log of fecundity when plotted against the log of other parameters of fish showed a straight line relationship (Figs. 4.6 to 4.9). Similar relationship of fecundity with various body measurements have been reported by Desai (1982); Dobriyal and Singh (1987, 1989); Agarwal *et al.*, (1988); Singh *et al.*, (1988), Singh (1999), Pandey (2001), Phukan and Biswas (2002).

Clark (1934) suggested that the fecundity of a fish increases in proportion to the square of its length. Simpson (1951) concluded that the fecundity of Plaice was related to the cube of its length. Lehman (1953) showed that there is a direct proportional increase in fecundity with size, weight and age in American shad.As in the present case the linear relationship between fecundity, length and weight of fish and ovary have been reported by several authors (Kesteven, 1942; Lehman, 1953; Bagenal, 1957; Sarojini, 1957; Joshi

and Khanna, 1980; Varghese, 1980; Pathani, 1981; Singh *et al.*, 1982; Tomasini *et al.*, 1996; Singh and Singh, 2001; Pandey, 2001; Phukan and biswas, 2002)

In the present study on *P. sophore* the fecundity was found to increase with an increase in the body measurements. In all cases a linear relationship was observed between fecundity and the body parameters.The values of correlation coefficient (r) (Table 4.9) indicated that the fecundity was more closely related to the ovary weight (r=0.954792) and fish length (r=0.91047) than fish weight (0.889596) and ovary length (r= 0.73668). Analysis of variance ('F' test) proved the linearity of regression (Table 4.8) between fecundity and body parameters. The 'F' test shows that all the relationships are significant at 1% level. This also indicates that fecundity depends on the fish length, fish weight and ovary length and ovary weight. Relative fecundity (number of eggs per gram body weight) was found in increasing order with the increase of fish weight and ovary weight.

The present study concludes that although the fecundity increased with an increase in the body measurements yet the fecundity was more closely related to the ovary weight (r=0.95479) and fish length (r=0.91047) than fish weight (r = 0.88959) and ovary length (r= 0.73668). The analysis of variance confirmed the linearity of regression between fecundity and body parameters.

Studies on the sex ratio have their own significance not only in detecting differential fishing if any, but also the predominance of a particular sex in different periods of the year and throughout the year (Koblitskeya, 1961). According to Nikolsky (1976), the sex ratio varies considerably from species to species but in majority of species it is close to one. It differs from one population to another of the same species and may

vary from year to year in the same population, males often predominate at first and females at the end. Shrestha (1994) observed the predominance of female among older age groups. However, Pathani (1984) observed that the male population was higher than females in the water of Kumaun in the month wise sex ratio.

Pillay (1958) in *Hilsa ilisha* and Jhingran (1961) in *Setipinna phasa* have observed a normal sex ratio (1:1). In *Garra mullya*, a hillstream fish, sex ratio of 1:1.44 between male and female was observed by Somavanshi (1981). Various workers have also studied this in different fish species like Pantulu, 1963; Vasudevappa and James, 1980; Pokhriyal, 1986; Khan *et al.*, 1996; Watson,1998; Pandey, 2001; Oliva-Paterna *et al.*, 2002; Neethisilvan *et al.*, 2002.

In the present study, a sex ratio of 1: 1.86 was found to differ significantly in different months from the expected ratio of 1:1 with females predominance which is based on 605 specimens including 211 males and 394 females. The chi-square analysis revealed that most of the values are significant (Table 4.10) that means the variation in the sex ratio from natural one (1:1) is more.

Table 4.1: Classification of maturity stages of *Puntius sophore* and comparison with I.C.E.S. scale (Wood, 1930)

Maturity stage	*Range of ova diameter in omd (1omd = 0.0156 mm)*	*Peak value*	*I.C.E.S st*
I immature	5-20	5	I,II
II maturing I	5-30	10	III
III Maturing II	5-40	15	IV
IV Mature I	10-50	50	V
V Mature II	10-60	60	VI
VI Spent	10-40	15	VII

Table 4.2 : Percentage occurrence of different maturity stages during different months in *P. sophore*

Months	*I*	*II*	*III*	*IV*	*V*	*VI*
January	44.83 (13)	55.17 (16)				
February	37.5 (15)	62.5 (25)				
March		44.44 (16)	55.56 (20)			
April		37.04 (10)	62.96 (17)			
May			39.02 (16)	60.98 (25)		
June			16.67 (7)	47.62 (20)	35.71 (15)	
July				12.5 (5)	87.5 (35)	
August					87.50 (28)	12.50 (4)
September	5.88 (2)					94.12 (32)
October	100 (20)					
November	100 (25)					
December	96.43 (27)	3.57 (1)				

Table 4.3: Monthly variation in Gonadosomatic index (GSI) of *Puntius sophore*

Month	*Gonadosomatic index*	
	Male	*Female*
January	0.367±0.103	0.899±0.271
February	0.8025±0.127	3.261±2.539
March	0.922±0.146	5.853±1.447
April	1.271±0.311	6.225±1.953
May	1.428±0.377	7.517±2.504
June	1.608±0.203	8.918±2.668
July	1.849±0.671	12.075±4.794
August	1.561±0.147	11.382±1.548
September	1.233±0.5149	6.752±1.096
October	0.299±0.1812	0.486±0.2302
November	0.306±0.031	0.533±0.077
December	0.346±0.104	0.727±0.290

Table 4.4 : Percentage occurrence of mature (male) *Puntius sophore* (Ham.) during prespawning and spawning season in various size groups (May- August)

S. No.	*Size – group (mm)*	*Total no. of fish*	*No. of mature fish**	*Percentage of mature fish*
1	41-50	8	1	12.5
2	51-60	9	4	44.44
3	61-70	31	21	67.7
4	71-80	22	20	90.9
5	81-90	9	9	100
6	91-100	2	2	100

Table 4.5 : Percentage occurrence of mature female *Puntius sophore* (Ham.) during prespawning and spawning season in various size – groups (May – August)

S. No.	*Size – group (mm)*	*Total no. of fish*	*No. of mature fish**	*Percentage of mature fish*
1	41-50	1	-	-
2	51-60	12	3	25.0
3	61-70	23	13	56.5
4	71-80	28	22	78.6
5	81-90	39	35	89.7
6	91-100	36	36	100
7	101-110	05	05	100
8	111-120	04	04	100

Table 4.6: Relationship between fish length, ovary weight and fecundity in *P. sophore*

Total length o fish (mm) Range	*Number of fish examined*	*Weight of ovary (g)*		*Fecundity*	
		Range	*Average*	*Range*	*Average*
50-60	3	0.105-0.130	0.119± 0.013	439-559	510±62
61-70	6	0.200-0.435	0.318±0.099	368-1941	1010±678
71-80	11	0.305-1.230	0.753±0.34	783-7041	4252±1872
81-90	12	0.980-2.310	1.381±0.355	4095-14330	7093±2745
91-100	14	1.400-2.945	1.966±0.545	7000-16816	11131±3016
101-110	12	1.940-3.503	2.837±0.585	11849-15550	13251±1517
111-120	4	3.250-3.530	3.405±0.116	16353-24385	19906±3332

Table 4.7: Relationship between fish weight, ovary weight and fecundity in *P. sophore*

Weight of fish (gm) Range	*Number of fish examined*	*Weight of ovary (g)*		*Fecundity*		*Relative fecundity*
		Range	*Mean± S.D.*	*Range*	*Mean ± S.D.*	*Range (Mean)*
1-4	3	0.105-0.130	0.119±0.013	439-559	510±62	177-219 (194)
5-8	18	0.200-1.230	0.589±0.099	368-5886	3080±1080	61-297(199)
9-12	18	0.980-2.310	1.487±0.365	4095-14330	7992±2659	455-1592(734)
13-16	12	1.400-2.945	2.076±0.512	7000-16816	11701±3074	538-1121 (766)
17-20	6	2.520-3.305	3.082±0.302	11849-15550	13277±1480	658-863 (775)
21-24	4	3.250-3.505	3.398±0.107	16116-19763	17838±1873	711-823 (794)
25-28	1	3.530	3.530	24385	24385	938

Table 4.8: Analysis of variance (ANOVA) between fecundity and body parameters of *P. sophore*

Parameters	Source	Df	SS	MS	F
Fish length and fecundity	Regression Residual Total	1 61 62	11.2214 2.3152 13.5366	11.2214 0.03795	295.6501
Fish weight and fecundity	Regression Residual Total	1 61 62	10.71265 2.824013 13.53666	10.71265 0.046295	231.3982
Ovary weight and Fecundity	Regression Residual Total	1 61 62	12.3404 1.196265 13.53666	12.3404 0.019611	629.262'
Ovary length and Fecundity	Regression Residual Total	1 61 62	7.34649 6.190171 13.53666	7.34649 0.101478	72.39475

- Values are significant at 1% level ($P_{0.01} = 3.92$)

Table 4.9 Summary of regression analysis *P.sophore*

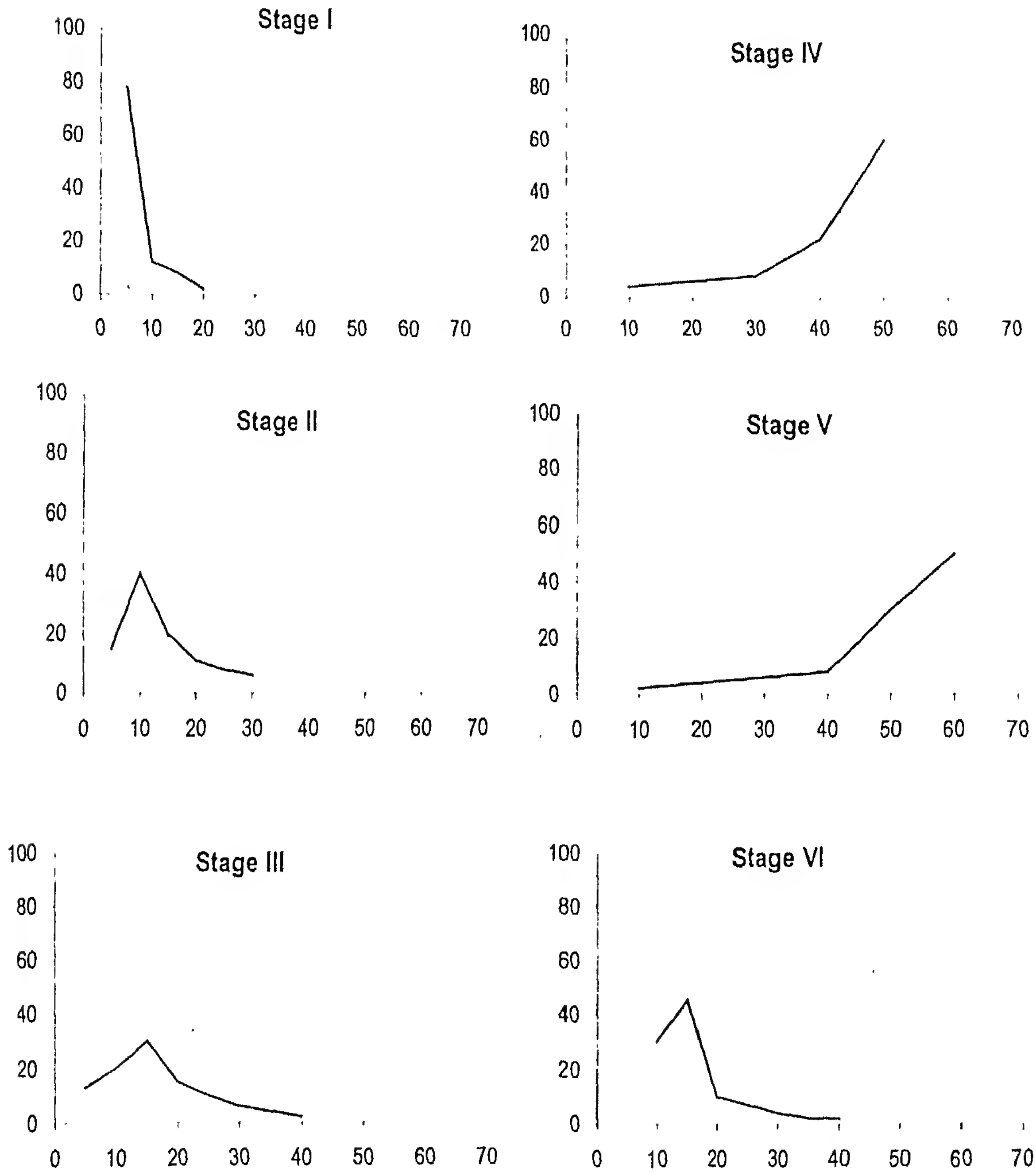
Regression Statistics					
Parameters	***Multiple R***	***R Square***	***Adjusted R Square***	***Standard Error***	***Observation***
Fecundity & Fish length	0.910475	0.828964	0.82616	0.19482	63
Fecundity & Fish weight	0.889596	0.79138	0.78796	0.215163	63
Fecundity & ovary length	0.736689	0.542711	0.535214	0.318556	63
Fecundity & ovary weight	0.955479	0.911628	0.910179	0.140039	63

Table 4.10: Sex ratio of *Puntius sophore*

Months	*Total number of fish examined*	*No. of male fish*	*% of male fish*	*Number of female fish*	*% of female fish*	*Sex ratio*	*Chi – square*	*Remarks*
Jan	43	14	32.6	29	67.4	1:2.1	5.23	***
Feb	56	16	28.6	40	71.4	1:2.5	10.29	****
March	58	22	37.9	36	62.1	1:1.36	3.38	**
April	39	12	30.8	27	69.2	1:2.25	5.77	***
May	55	14	25.5	41	75.4	1:2.9	13.25	****
June	49	7	14.3	42	85.7	1:6.0	25.0	****
July	73	33	45.2	40	54.8	1:1.21	0.67	*
August	51	17	33.3	34	66.7	1:2.0	5.67	***
September	59	27	45.8	32	54.2	1:1.18	0.42	*
October	27	7	25.9	20	74.1	1:2.85	6.26	***
November	45	20	44.4	25	55.6	1:1.25	0.56	*
December	50	22	44.0	28	56.0	1:1.27	0.72	*
Total	605	211	34.9	394	65.1	1:1.86	55.35	

* Non significant (>2.7); ** Significant at 10% level ($\chi^2_{0.1} = 2.70$);
*** Significant at 2.5% ($\chi^2 0.025 = 5.023$); **** highly significant.

Fig. 4.1 : Ova diameter frequency polygons of the ovaries of *P. sophore* at different maturity stages



X axis - %
Y axis - ova diameter

Fig. 4.2: Percentage occurance of different stages of ovaries in *P. sophore*

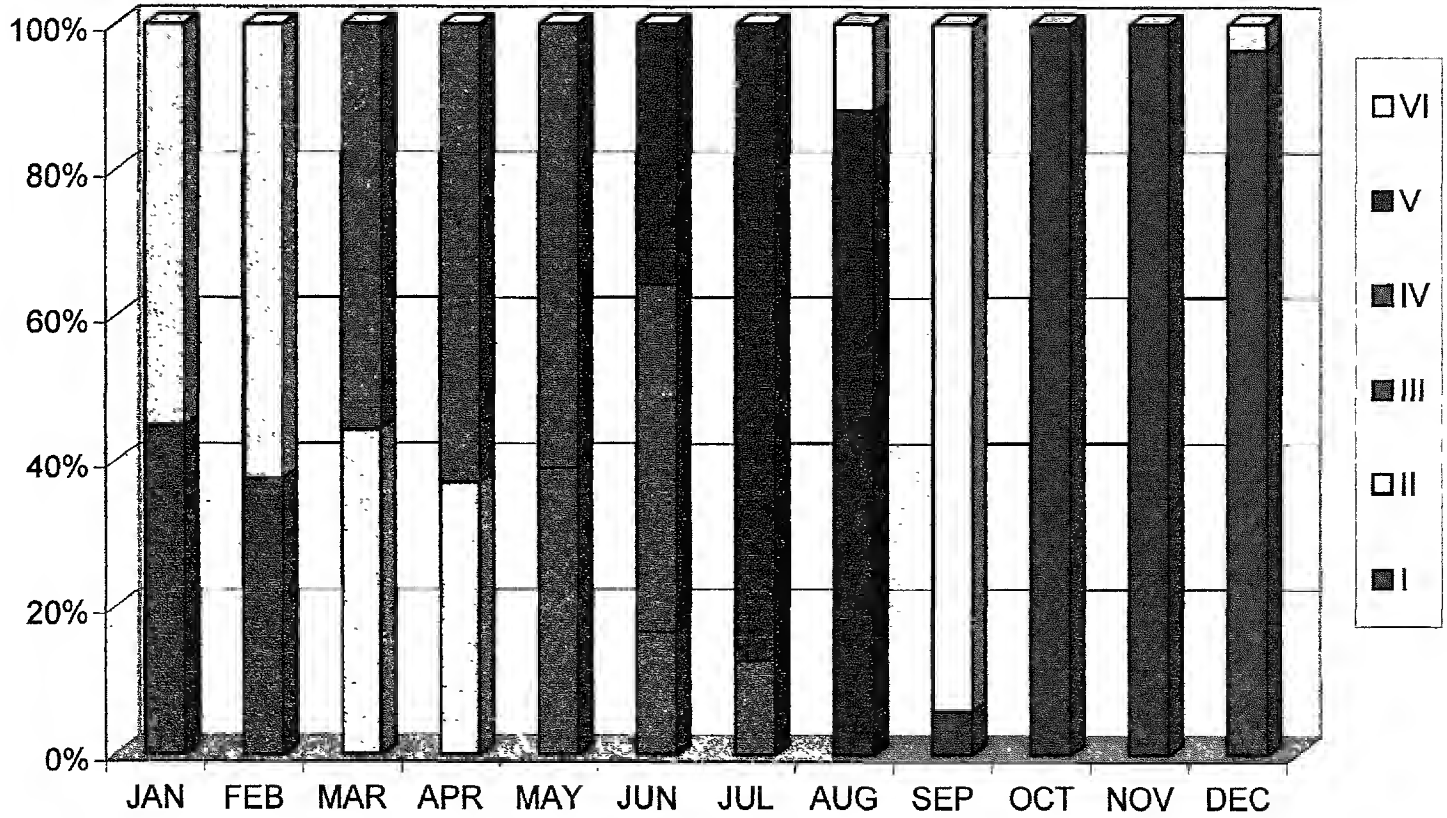


Fig. 4.3: GSI values of female *P. sophore* during different months

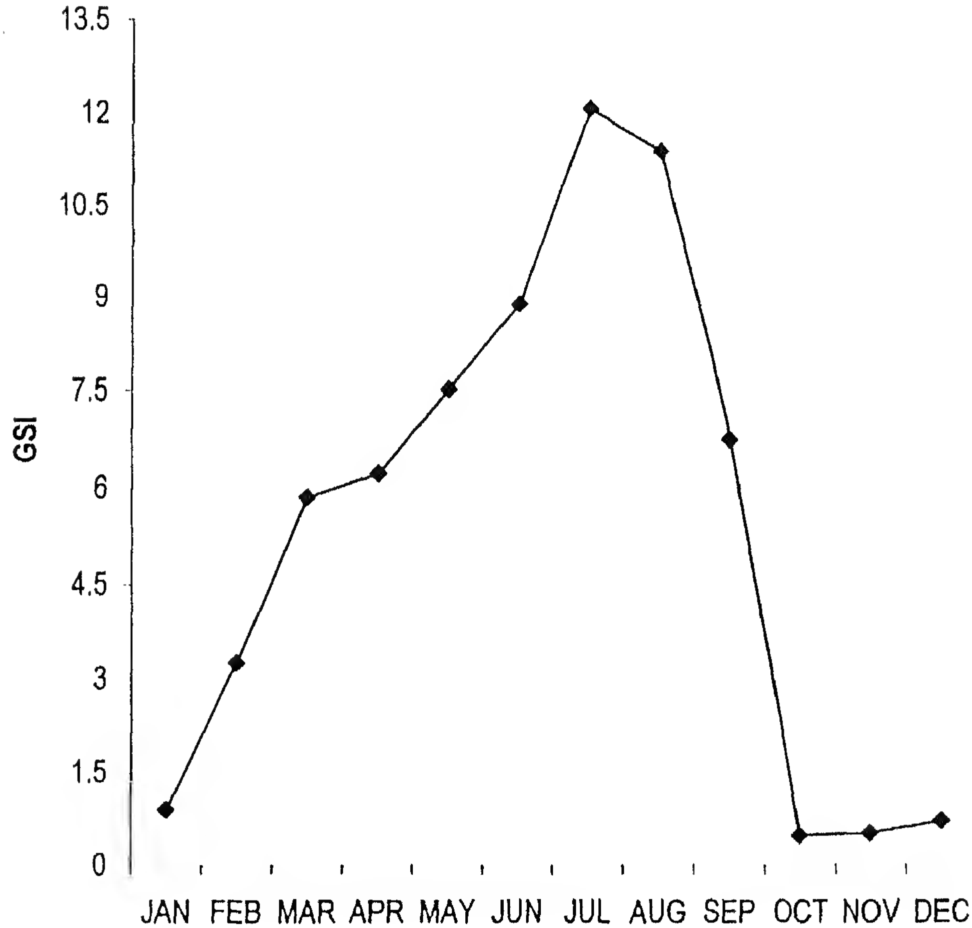


Fig. 4.4: GSI values of male *P. sophore* during different months

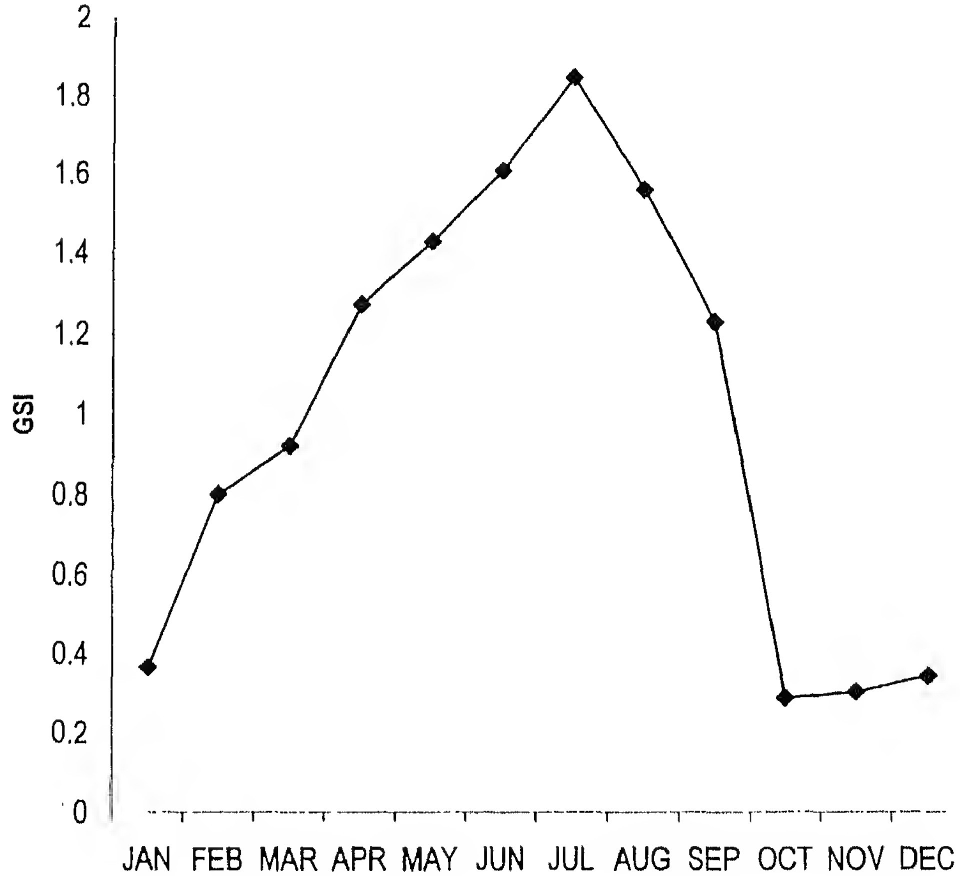


Fig. 4.5: Size at first maturity of Puntius sophore

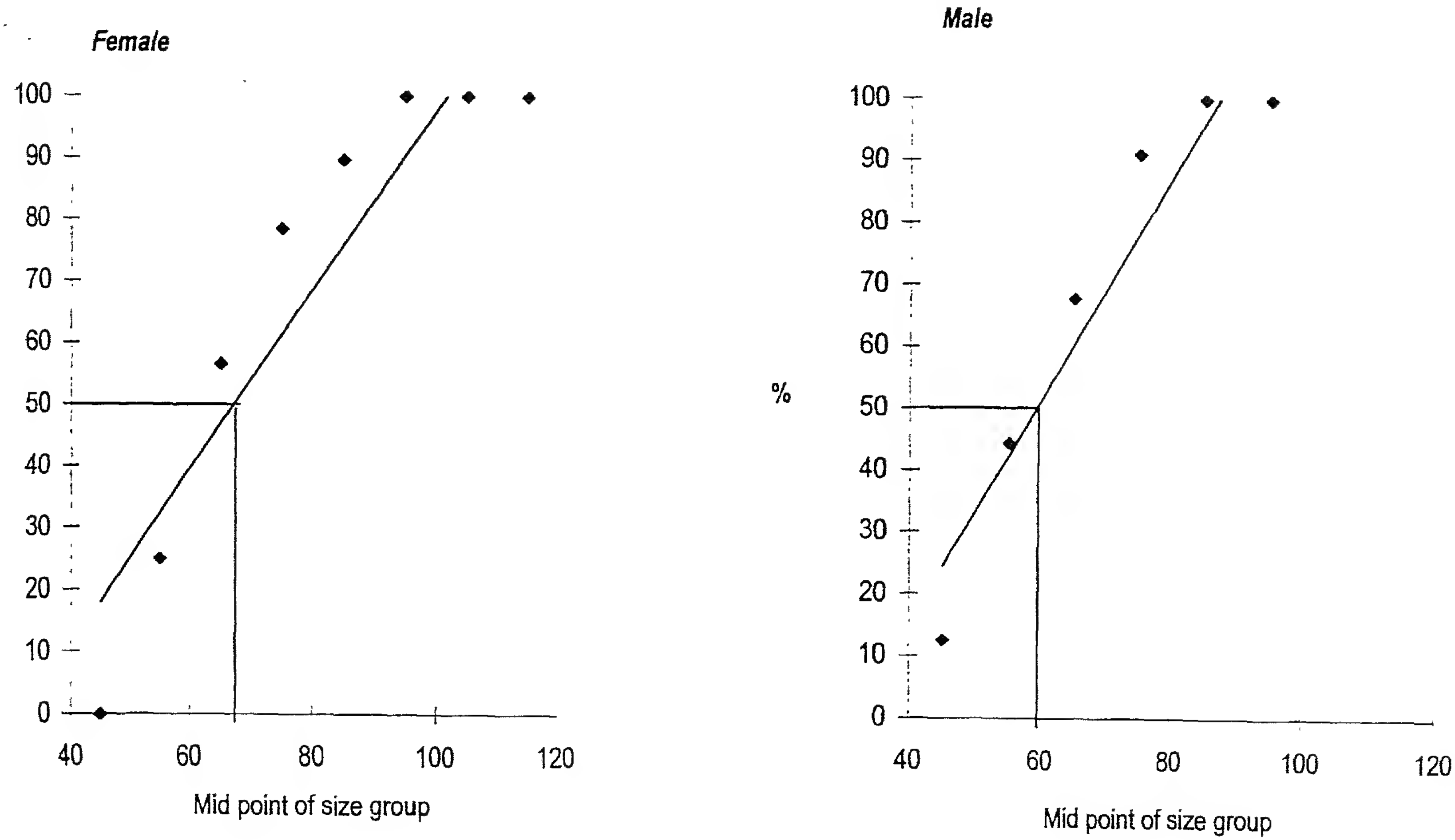


Fig. 4.6 : Fish length - fecundity relationship in *P. sophore*

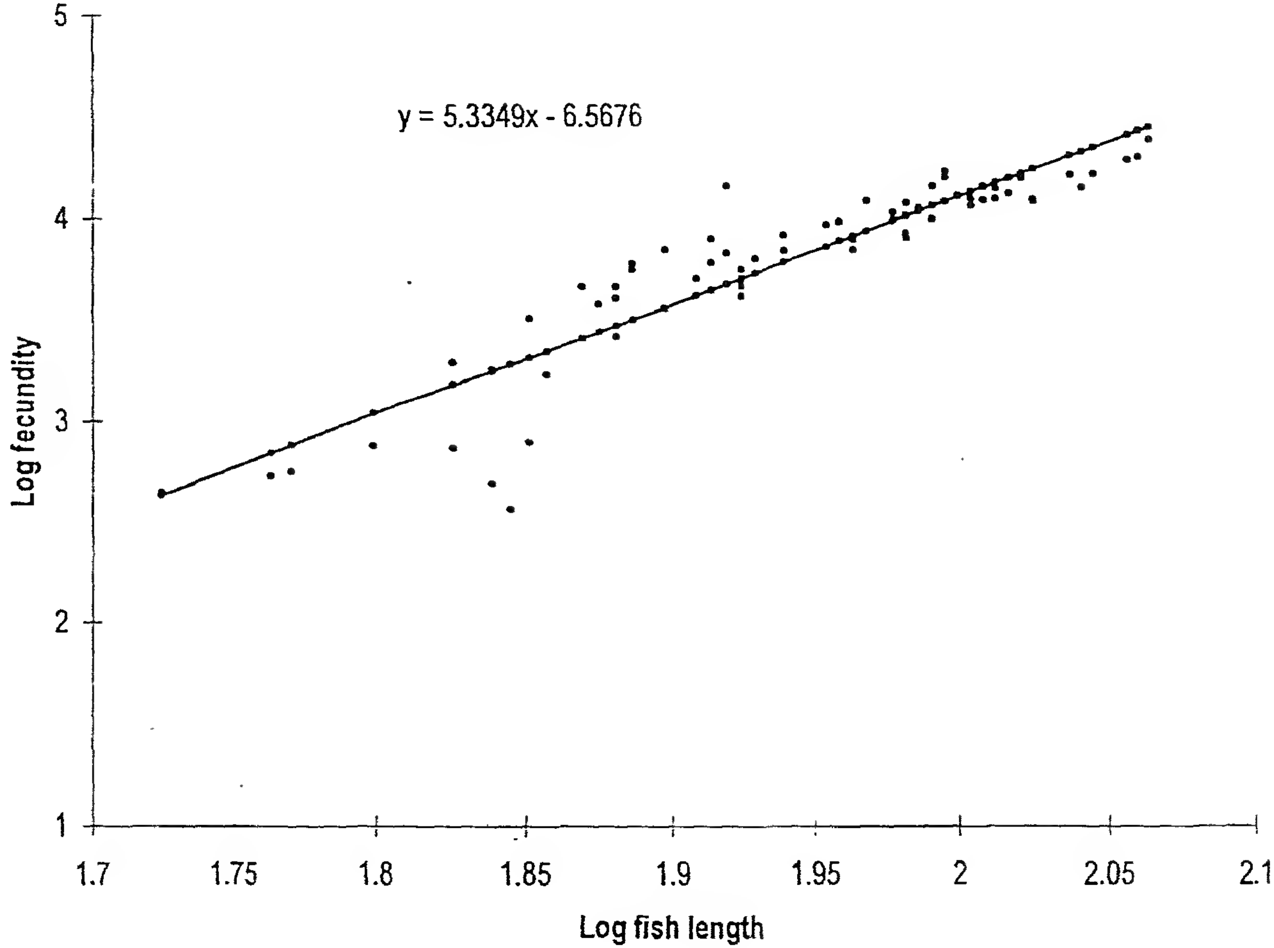


Fig. 4.7 Fish weight - fecundity relationship of *P. sophore*

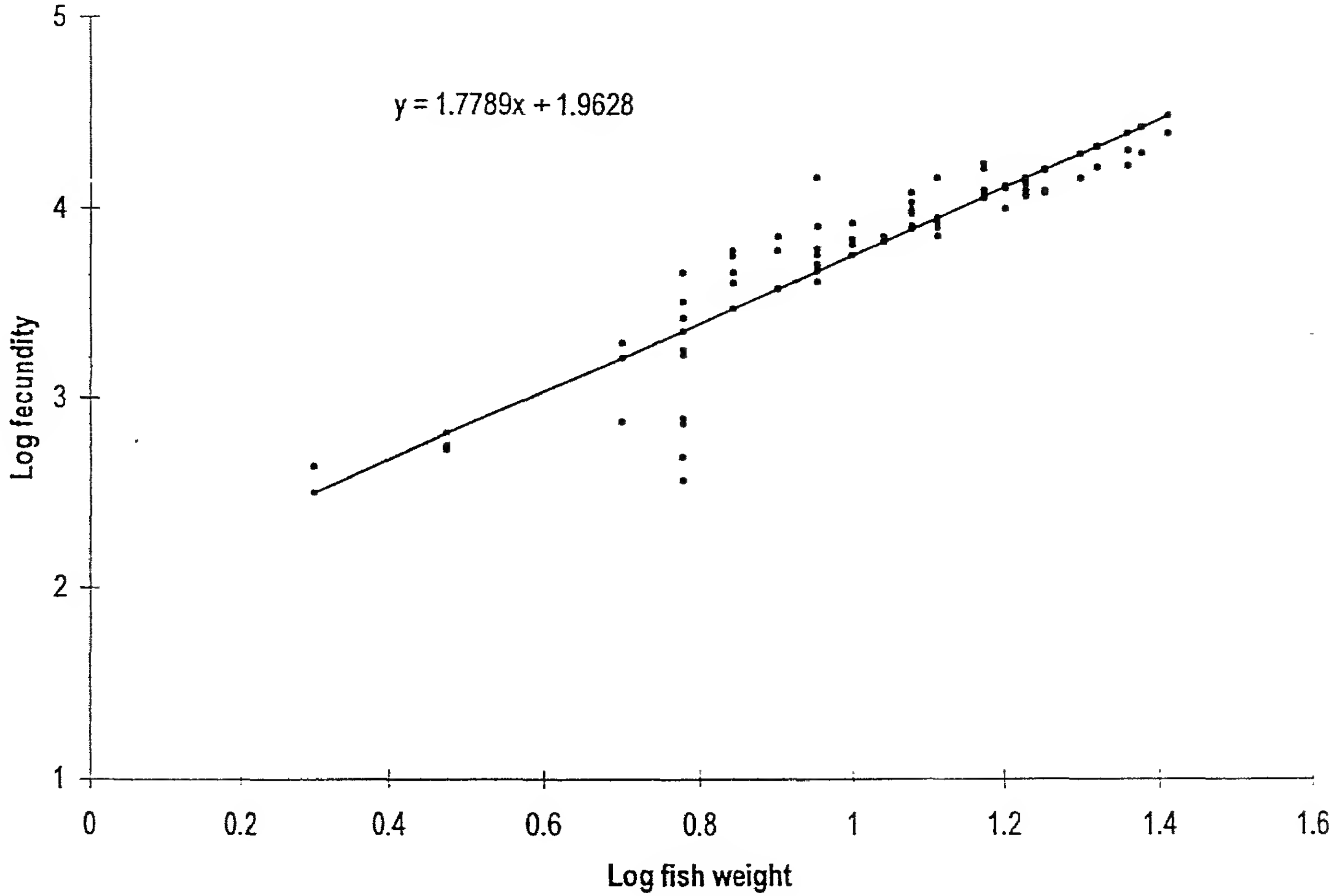


Fig. 4.8 : Ovary length - fecundity relationship in *P. sophore*

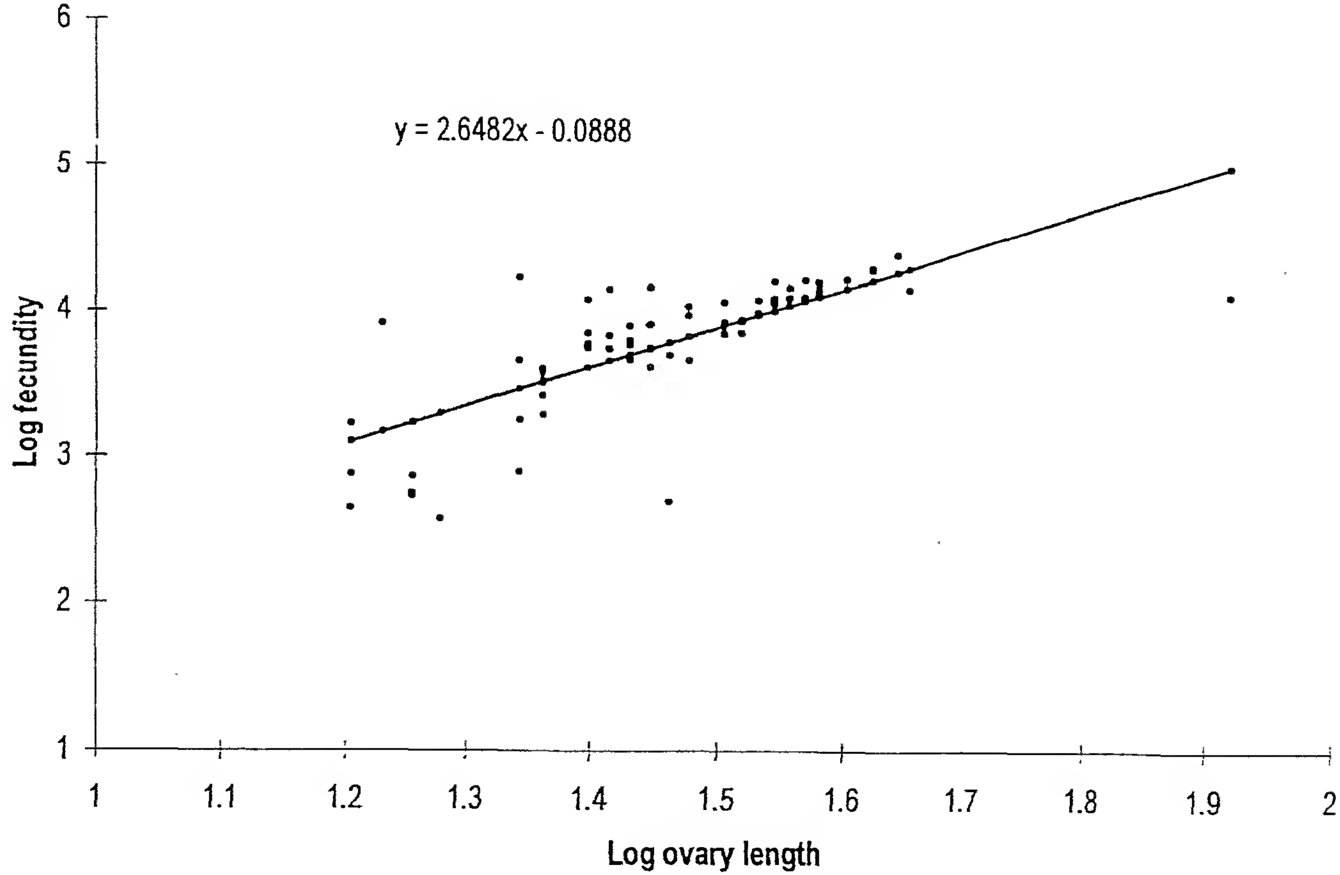
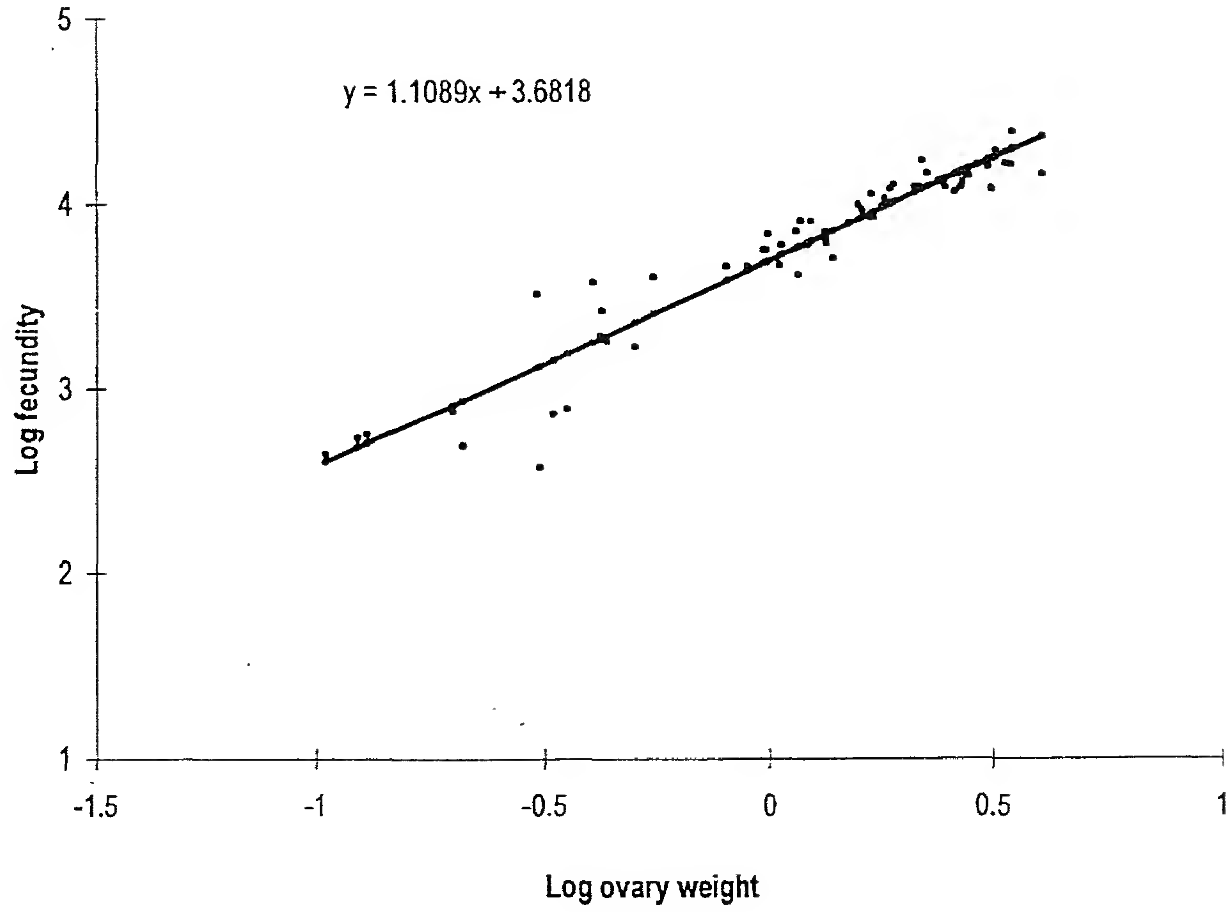


Fig. 4.9 Ovary weight - fecundity relationship in *P. sophore*



CHAPTER VII

AGE AND GROWTH

AGE AND GROWTH

INTRODUCTION

Age and growth is an important aspect of fishery biology. The annual variation in fishery depends upon its growth pattern. Growth of an organism means a change in length or weight or both with increasing age, due to the conversion of the food material into the building energy of the body by means of the process of nutrition. The age determination is a method to understand the composition of a fish population with regard to the age classes and the role of a particular year classes in a the fluctuations of the fishery, the calculation of the mortality rates and success of individual year classes.

A knowledge of age and growth rate of fish is an extremely useful part of fishery biology, fishery management and population dynamics. In fishery management, it is significant for determining past and future status of fishery as they give an idea about the catch composition of the fishable stock, its survival, age and mortality rates.

Age and growth in conjugation with length and weight provide basic information on longevity, sexual maturity or spawning time, harvestable size, size at first maturity, environmental conditions of the water bodies and suitability for stocking of a particular fish species. These studies are also useful in selecting the progeny of the fast growing brooders for culture fisheries.

Further, a comparison of rate of fish growth in different water bodies, may partly identify good or bad environmental conditions and point the way for future action. Thus,

these studies are fundamentals, helping in the forecast and scientific exploitation of a fishery.

Different methods have been evolved for determining the age of fish in the course of progress in fishery research. The known age method is a sure test of the age of the fish and hence of length and weight but this method is applicable in culture fisheries only. Another method is that of tagging and clipping, releasing and capturing and is often used in capture fisheries. This is costly and often time consuming. The most frequently used method of age determination is the interpretation and counting of growth zones or number of periodic ring or growth checks which appear in the hard part of fishes. The hard parts that can be studied for age determination are the scales, dorsal and pectoral spines, opercular bones, coracoids, hyomandibular etc. Out of all these structures, scales have been widely used to assess the age and growth. Age assessment of fish from their calcified structures is a vital component of the most of our present day fishery managements. Those that are considered to be formed annually are called year marks, annual marks, annual rings or annuli. These are formed during alternate periods of faster and slower growth (or no growth at all) and reflects various environmental or internal influences. In temperate regions, the period of little or no growth usually occurs between the beginning of winter and early summer. In general, the greater the seasonal temperature differences, the clearer are the annual marks.

Amongst the various hard parts, scales can be collected with ease without causing visible enjury to the fish. Therefore, scales have been successfully used in many countries for the determination of age, growth and their parameters. For the study of age and growth, the scales located between the lateral line and the base of dorsal fin are often

used and designated as 'Key scales' (Chugunova, 1963; Anon, 1968; Bagenal, 1974; Bagenal and Tesch, 1978). An important advantage in using scales for these studies is that they continue to grow in size with increase in fish length. Since fishes show intermediate growth and the number of scales remains constant throughout life.The basic concept in the scale study is to identify correctly the annual marks and larval marks for counting the number of years.

A knowledge of scale structure is very useful in the interpretation of the growth zones. The scale structure of fish help to interpret many happenings of its life. SEM studies of fish's scale surface will be useful in taxonomy, phylogeny and identification of the true, false and larval annuli in different groups of fishes. The study of earlier literature reveals that very few attempts have been made in the past on the scale structure of fishes by SEM.

The use of scales for age determination was first attempted in *Cyprinus carpio* (Hoffbaurer, 1898) and since than the methodology has scaled new dimensions, especially with advent of computers. Lea (1910) used Norwegian herring scales and concluded that the growth of the scale so closely accords with the growth of the individual that it is possible with a certain amount of exactness to describe the growth history by measuring the growth zones of the scales. Thus the scale of the fish not only gives the data concerning the size of the fish at a given age, but also the size of the fish at each previous year of its existence. From such observations, it should be possible to trace a connection between physical condition and the growth of the fish. If the relationship of the fish length to any scale radius is linear the previous lengths can be calculated by the formula,

$ln / l = Sn / S$ (Lea, 1910)

where, ln = length of the fish when annulus 'n' was formed, l = length of the fish when scale sample was obtained, Sn = radius of annulus 'n' (at fish length ln), S = total scale radius.

Fraser (1916) observed that the scale appeared on the body of the fish after fish had attained some length, which is different in different fishes. The particular size when scale appeared known as correction factor. He modified the formula given by Lea (1910) for back - calculated length by incorporating the correction factor. Back - calculation is a technique that uses a set of measurements made on a fish at one time to infer its length at an earlier time or times (Francis, 1990). The above method of back - calculation is known as intercept- corrected direct proportion method

and is applicable only when the intercept of the relationship between fish length and hard part radius is not at origin.

Back calculated lengths have been used for a variety of purposes, including increasing the number of observations in length-at-age data, estimation of length at ages that are rarely observed (Hickling, 1933; Morales, 1984) and comparison of growth between sexes (Kraiem, 1982; Davis and West, 1992; D'Onghia *et al.*, 2000), population of the same species (Gee, 1978; Graynoth, 1987) and different species (D'Onghia *et al.*, 2000).

Some of the important contributions to the age and growth rate determination of fish during recent years have been made by Jacot (1920), Hutton (1923), Van Oosten (1929), Robertson (1933), Hile (1942), Moghe (1946), Carlender (1943), Kuzmin (1947), Nair (1949), Chacko and Krishnamoorty (1950), Raj (1951), Seshappa and Bhimachar

(1951, 1954), Oliva (1955), Jhingran (1957), Jensen and Clark (1958), Regier (1962), Balon (1963), Frost (1963), Natrajan and Jhingran (1963), Toor (1964), Qasim and Bhatt (1966), Croagg-Hine and Jones (1969), Kamal (1969), Hile (1970), Poupe (1973), Carlender (1974), Bagenal (1974),Dudley (1974), Steinmetz (1974), Griffith (1975), Islam and Strawn (1975), Murty (1976), Tandon and Oliva (1978), Walfort and Miller (1978), Linfield (1979), Frost and Kipling (1980), Stanley (1980), Cadwallader (1983), Pokhriyal (1986), Sinis and Economidies (1987), North (1988), Dobriyal and Singh (1990), Casselman (1990), Nautiyal (1990), Tandon *et al.*, (1992), Singh and Sharma (1995), Bisht *et al.*, (1996), Rawat and Nautiyal (1996), Rawat (1998), Singh (1999), Johal *et al.*, (2000), Nurulamin *et al.*, (2001), Dobriyal and Negi (2001), Johal *et al.*, (2001), Oliva-Paterna (2002), and Tandon and Johal (2003).

The present study gives an account of age and growth determination in *Puntius sophore*.

OBSERVATIONS

Age determination was carried out using two methods, based on scale study and based on length frequency distribution.

(A) Scale structure

The scale of *P. sophore* is cycloid (Fig. 5.1) is as long as its breadth and focus lies almost in the centre. The scale has three fields- anterior, posterior and lateral. The visible part of the scale on the body of the fish is the posterior face which is rough and bears chromatophores. The anterior face is smooth, embedded in the skin and is overlapped by the preceding scale. The part of scale which is attached to the skin is shiny and opposite part is hard due to the presence of elevations of circuli. The posterior side of the scale is

rounded whereas anterior side is wavy. The scale has circular lines called circuli and the radiating lines originating from the focus are called radii. The circuli are formed periodically with the growth of scale showing closely and widely spaced arrangement. The radiating lines are formed due to less space on the body of the growing scale. Radii are clearly visible on the anterior side as well as on the posterior side.

To understand the detailed structure of circuli, radii, annular zone, posterior part, anterior part and chromatophores etc. SEM (Scanning Electron Microscopy) studies were carried out. The central part of scale is shown in Figs. 5.4. Focus is well defined and rounded structure in the scale of *P. sophore*. It is located in the centre of scale. Under the ordinary magnification, the larval mark can not be distinguished whereas in SEM it is very clear (Fig. 5.4). It is located very near the focus. This mark appears during the first year of life. In the biggest scale the focus region become cracked due to the excess deposition of calcium salts (Fig. 5.5).

From the focus or around the focus there are present growth rings known as circuli. The scale is peculiar in having very conspicuous and well marked circuli, all round the focus. The circuli are not circular in fashion. They run horizontal in the anterior side (Fig. 5.2), parallel in the lateral side (Figs. 5.7, 5.8, 5.9) whereas oblique on the posterior side (Figs. 5.3 and 5.6).In the posterior side of the scale the circuli are showing convergence. The circuli are seem to be without lepidonts (tooth-like structures). The posterior side of the scale is slightly more tough than the anterior side because it is exposed part whereas anterior side is overlapped by the posterior part of the preceding scale. In Figs 5.11, 5.12 and 5.13 the posterior part of the scale is shown. In this part chromatophores are present

(Figs. 5.11 and 5.12) which impart specific colour to the fish. The shape of chromatophores or pigment granules varies from oval to semi-oval.

From the outer margin of the focus the radii make their appearance . The radii cut the circuli at right angles (Fig. 5.4). These radii break the circuli and make the canal known as radial canal (Fig. 5.10). The radial canal serves as a channel to carry the nutrients. At a same time the mucus is also spread to the body through this canal. In the radial canals the intercircular distance, there are mucus pores. Normally the circuli show very characteristic regular pattern but in the annular zone they become disorganised and they become wavy (Fig. 5.14). The annulus is formed due to discontinuation of circuli (Fig. 5.14). The circuli when exhibited the tendency of discontinuity were identified as annuli or growth rings (Figs 5.15 to 5.19). Thus each annulus comprised continuous and widely spaced (fast growing phase) and closely and discontinuous circuli.

During the course of investigation, the regenerated scales were also found which constituted only 5-6% of the total number of scale examined. The regenerated scale (Fig. 5.20) have disorganised focus and irregular circuli. The annuli appear only in the marginal area which have developed after regeneration. These scales are replaced when the original scales are lost due to mechanical injury (Chugunova, 1963). Regenerated scales are mostly small in size and soft as compared to the normal ones. They have been excluded from the present study. Fig. 5.21 shows the lateral line scale. In lateral line scale lateral line canal is clearly visible.

(B) Growth

Fish length - scale radius relationship

A linear relationship with high degree of correlation coefficient (r) has been observed when total fish length was plotted against lateral scale radius (Fig. 6.1). The equation obtained was :

$$SR = -4.4696 + 0.6613\ FL \quad (r = 0.8863)$$

Where, FL = total length of fish

SR = lateral scale radius

r = correlation coefficient

The regression line based on this equation when extrapolated, cut the x-axis at 8 mm. It is evident that scales appeared for the first time on the fish's body, when the fish had attained the length of 8 mm. Hence, this value has been considered as correction factor and used for the calculation of back calculated lengths.

Time and causative factors for ring formation

In the present study, the highest number of fishes having marginal annuli was observed in July and August. The percentage of scales possessing minimum width in terminal zone were found maximum 92.8% in July and 100% in August (Table 6.1 and Fig. 6.2). Thus, the probable months of age ring formation were July - August. As the peak was observed only once in monsoon, it could be easily concluded that there is only one frequency of ring formation. The fish spawns during July - August which probably disturbed the normal growth causing the discontinuity in the growth of circuli (identified as annulus) (Figs. 5.15 to 5.19). During these months very low feeding intensity was recorded with empty gut. As far as cause of ring formation is concerned, it was concluded that a

consortium of factors like spawning and low feeding stress were causative factors for ring formation in *Puntius sophore.*

Back-calculation

During the period of investigation scale samples of 512 specimens of *Puntius sophore* ranging in length from 44 to 116 mm and belonging to 0 to 4 age classes were examined. The maximum number of specimens belonged to age class 2. The mean back calculated length (in mm) obtained by the analysis of pooled key scales sampled were 48, 64, 79 and 95 for first to fourth age classes respectively (Table 6.2)

Growth parameters

Summary of the growth data of *Puntius sophore* is presented in Table 6.3.

Annual length increment (h)

The annual length increment (h) was observed to be 48, 16, 15 and 16 during first, second, third and fourth year of life. The maximum annual increment has been observed in the first year of life which generally decreased with the increase in age. However, its value showed slight increase in the age class four.

Specific rate of linear growth (C_l)

The specific rate of linear growth (C_l) was observed to be 33 between first and second year, 23 between second and third year and 20 between third and fourth year. It showed a decreasing trend.

Index of species average size (ϕh)

Index of species average size, i.e., average increase in length for *P. sophore* was observed to be 23 (Table 6.3). A high value of ϕh indicates better growth and suitability of environment.

Growth characteristic (C_{th})

The value of growth characteristic (C_{th}) calculated for *Puntius sophore* in the present study showed lowest growth (13.1) during first and second year which increased in second and third year (13.5) and third and fourth year (14.5). The maximum growth was of course between third to fourth year of life.

Growth constant (C_{lt})

The growth constant (C_{lt}) studied for *Puntius sophore* showed that there were two phases of life up to one year, it was immature phase (0.4) and from 2 to 4 years it was mature phase (0.25). *Puntius sophore* do not enter old age. These phases were classified on the basis of observations made by Tandon and Johal (1994).Growth compensation has not been recorded in this fish.

C. Length frequency distribution

Age of *P. sophore* was determined by back-calculation was confirmed by length frequency distribution method of Petersen which is based on the expectation that when data for a sample of the entire population are plotted, there will be clumping of fish of successive ages about successive given lengths, making possible a separation by age group. This lends support to the age assessed by back calculation method.

The length frequency distribution of 512 fishes was plotted (Fig. 6.3). The clumping in population was recorded at 52 mm, 67 mm, 81 mm and 92 mm which showed this length to be in first, second, third and fourth year respectively.

D. *Harvestable size*

The harvestable size, calculated for the fish by plotting length increment in percentage of the length of first growth season, and length in percentage of final growth

season, was calculated as 62.0 mm which the fish attains in about 1 year and 10 months (Fig. 6.4)

E. *Age at first maturity*

On plotting size at first maturity with years, the age at first maturity was calculated, which came to be below two years for male and above two years for female *Puntius sophore* (Fig. 6.5).

DISCUSSION

The age and growth is one of the most intensively studied aspects of fishery biology. In any fishery management, the determination of age and rate of growth occupies a key place, because of its significance from scientific and commercial view points.

Growth is commonly considered to increase gradually with time in size or mass or some kind of living unit and it results from the consumption of food, its assimilation and the construction from it of the organism's body (Vasnetsov,1953). The growth process is specific adaptive property, ensured by the unity of the species and its environment. A characteristic feature of the growth of fishes is its periodicity.

Determination of age in fishes depends on the annual growth marks in certain skeletal part of fish (scales, otoliths, bones, etc.). These growth marks are formed as a result of the fluctuation in the growth of fish which is not uniform throughout the year. This fluctuating periodicity of the faster and slower growth of the fish expresses itself annually on the skeletal parts as periodic structures of wider (fast growing) and narrower (slow growing) zone. These expressions (growth marks) in *Puntius sophore* is annual in nature and used for ageing studies.

In the present study, a linear relationship with high degree of correlation was obtained between scale radius and fish length by plotting the length on X-axis and the corresponding lateral scale radius on Y-axis. The linear relationship between fish length and scale radius is also obtained by Johal and Tandon,1981; Johal and Tandon, 1983a,b; Johal and Tandon, 1987; Johal *et al.*,1987; Tandon and Johal, 1983; Tandon *et al.*,1989; Tandon *et al.*,1989; Jhingran, 1959; Natrajan and Jhingran, 1963; Kamal, 1969; Khan and Siddiqui, 1973; Tandon *et al.*,1991, Tandon *et al.*,1993; Singh (1999), Johal *et al.*,2001; Singh, 1999; Dobriyal and Negi, 2001, Tandon and Johal (2003).

In the past, mostly Indian major carps have been subjected to age and growth studies by Jhingran (1957, 1959), Natrajan and Jhingran (1963), Kamal (1969), Khandker and Hoque (1970), Hanumantharao (1974), Khan and Jhingran (1975), Jhingran and Khan (1979) using scales. However, other freshwater fishes of India also received the attention of the workers like Raj (1951), Qasim and Bhatt (1964, 1966) and Rammohana (1974). But these workers did not use correction factor. In Indian fishes, the correction factor was first used by Johal and Tandon (1981, 1983 a, b, 1985 and 1987a,b), Johal and Kingra (1988), Johal *et al.*,(1989), and Tandon *et al.*,(1989 a, b, 1991).

Development studies have also confirm that scales are formed after the fish had attained some length (Chakrabarty and Murty, 1972; Silverman, 1975). This observation has been confirmed while plotting the graph between the total length of fish and scale radius. The regresion line when extrapolated cuts the X-axis at a distance of 8 mm from the origin (Fig. 6.1). This length has been used as a correction factor in back calculation of the fish lengths at the formation of each annulus.

Some workers including Johal and Tandon, 1981; Johal and Tandon, 1983 a,b; Johal and Tandon, 1985; Johal and Tandon, 1987; Johal *et al.*, 1987; Johal and Kingra, 1988; Tandon and Johal, 1983; Johal *et al.*, 1984; Tandon *et al.*, 1989; Anon, 1968; Bagenal, 1974; Bagenal and Tesch, 1978; Summerfelt and Hall, 1987; Johal *et al.*, 1989; Holicik,1967; Johal, 1980 a, b; Vasnetsov, 1958; Singh, 1999; Dobriyal and Negi, 2001; Johal *et al.*, 2001, Tandon and Johal, 2003 have used these values in back calculation, whereas some workers have refrained from doing so (Jhingran, 1959; Jhingran, 1968; Natrajan and Jhingran, 1963; Kamal, 1969; Khan and Siddiqui,1973; Khan and Jhingran, 1975; Jhingran and Khan, 1979; Pathani, 1981; Hanumantharao, 1974; Ramamohana, 1974).

The first appearance of scales on the body of Indian major carps *Labeo rohita*, *Cirrhina mrigala* and *Catla catla* when they attained the size of 24 mm was reported by Chakrabarty and Murty (1972). Gandotra (1991) observed the first appearance of scale in *Cyprinus carpio*, *Rasbora rasbora* and *Puntius ticto* when these fishes had attained the size of 15-16 mm, 8-9.5 mm and 7-8 mm respectively. In the case of *Puntius sophore*, a correction factor of 8 mm was obtained and used for back calculations.

The use of hard parts, especially the scale, as age indicators has eluded most fishery biologist. The role of hard parts, especially scale, can not be over looked for the effective fishery management practices (Tandon and Johal, 1996). Amongst the various hard parts scales have been used for classification, identification and growth studies of different fishes (Chu, 1935; Lagler *et al.*,1977; Kimura *et. al.*,1979; Hecht, 1980; Vysokinski, 1983; Papaconstantinous, 1984; Baginiere and LeLouran, 1987; Johal and Tandon, 1992).

In the past various workers, such as Lee (1920), Robertson (1933), Van Oosten (1957), Jhingran (1957, 1959), Bhatt (1969), Johal (1979, 1980 a, b), Johal and Tandon (1983, 1985), Johal *et al.*,(1996); Johal and Agarwal (1997), and Johal *et al.*,(1999) Johal and Bansal (2000) worked extensively on the structure of scale in depth to make it suitable for age determination and growth studies.

In the present study, the detailed structure of circuli, radii, annular zone, posterior part and pigment granules was studied by using SEM (Scanning Electron Microscopy) technique. A perusal of literature has revealed that the scales of only a few bony fishes have been subjected to SEM studies in the past.

A few Indian workers like Johal and Dua, 1994; Dua and Johal, 1994, 1996; Johal and Sawhney, 1997; Sandhu, 1992; Kaur, 1993; Dogra, 1994; Mehta, 1994; Johal *et al.*, 1996, Johal and Bansal (2000) have studied the structure of annuli, circuli of different regions of cycloid scales and the impact of the pesticides on these structures of Indian freshwater fish species. Most of these workers have observed the characteristic features of these structures which can be species - specific or genera specific.

Fish scales have been used for various purposes on the basis of SEM technique. The scales not only provide the information on various growth parameters but are also very reliable tool for indicating pollution in water bodies (Johal and Dua, 1994; Dua and Johal, 1994; Johal and Sawhney, 1997). Scales are also useful in taxonomic studies (Lagler, 1947; Cockrell, 1909; Cockrell, 1910; DeLamater and Courtnay, 1973; Tandon and Sharma, 1977; Hollander, 1986)

Perusal of literature shows that the fish scale have been successfully employed for the identification of fishes. Various workers like Cockrell and Calloway (1909), Cockrell

(1912), Chu (1935). Kobayashi (1951), Koo (1962), Yang (1976) and Tandon and Sharma (1977) used the scale structure for framing the keys of fishes. Fish scales can also be employed as a reliable tool for sexual dimorphism. Johal and Thomos (2000) on the basis of SEM studies showed a clearcut sexual dimorphism in the scale structure of *Arilius bendelisis*. DeLamter *et al.*,(1972) used SEM studies of fish scale as an adjunctive aid in speciation. DeLamater and Courtney (1973) studied the scale of some teleostean fishes for the identification of different phenon and taxon.

DeLamater and Courtenay Jr (1973) undertook SEM studies on the lateral line canal of twelve teleostean fishes and found characteristic condition along the ridges of circuli in the same area. Lanzing and Hogginbotham (1974) described the detailed surface structure of the scale of *Tilapia mossambica* using SEM. They observed the characteristic denticles on the outer rows of circuli and characteristic tubercles on the posterior part. They observed pores on the caudal part indicating the position of mucus cells situated in the epidermal layer. Huges (1981) described the detailed structure of cteni in some perches belonging to the family Platycephalidae. Hollander (1986) described various types of denticles on the crests of circuli in twelve Poecid fishes. Verma (1990), while describing the morphology and dielectric properties of *Catla catla* scale observed oval or semi oval chromatophores in the posterior part of scale.

The present observations are similar to those of Verma (1990). In *P. Sophore*, lepidonts, denticles are absent. The present studies relating to SEM of scale may be helpful for future workers. It is felt that detailed SEM studies of fish scale surface will be useful in taxonomy, phylogeny and identification of true, false and larval annuli.

The annual marks on the basis of which the age is determined, vary from species to species and even in the same species from different water bodies (Johal and Tandon, 1987; Tandon and Johal, 1983; Regier, 1962). A true annulus runs all along the surface of scale and is formed almost at the same time year after year, whereas a false annulus does not run all along the scale and can be formed at any time due to any type of physiological stress (Annon, 1968; Bagenal, 1974; Bagenal and Tesch, 1978; Natrajan and Jhingran, 1963; Khan and Siddiqui, 1973; Khan and Jhingran, 1975) caused by environment (Chugunova, 1963).

On the scale of *Puntius sophore* are present of closely placed circuli followed by zones of widely spaced circuli on concentric rings. An annulus is formed at the outer border of closely spaced circuli. In the present study the larval mark observed very near to the focus and becomes indistinct as the scale grows (Johal and Tandon, 1981; Johal and Tandon, 1983; Johal and Tandon, 1987; Tandon and Johal, 1983; Tandon *et al.*, 1989; Chugunova, 1963).

During the present investigation the maximum occurrence of marginal annuli was observed in the month of July - August. The highest precentage of scales possessing minimum width in the terminal zone was found to occur during July (92.8%) and August (100 %), which indicated the formation of ring in these months. During the present investigation the maximum occurrence of marginal annuli was also observed in the month of July- August.

The problem of exact time of formation of annuli and various factors responsible for it, has been undertaken by various workers in India. DeBont (1967) described that in temperate waters, marks on the hard parts of the fish are in reality, although, they may be

shifting from one year to another, whereas in tropical fish, no such uniformity is found and different factors regarding the species and region seem to be responsible for the formation of annuli. In tropical region, the annuli develops as a result of cessation of growth during the unfavorable conditions.

Fagade (1974) observed the annulus formation on the scale of *Tilapia melanotheron* in the month of June - October, from Lagos Lagoon when the salinity is drastically changed and the fish starts migration. Lenanton (1978) found that annulus formation is associated with spawning which takes place in the month of June in Australian herring, *Arripis georgiarues*. Fry (1936) observed that an annulus is formed on the scale of *Hesperoleucas venustus* from May to July in USA and July to August in USSR. According to him, an annulus is formed 3-4 weeks after spawning.According to Menon (1953) and Chugunova (1963) in the tropical regions, the annuli develops as a result of cessation of growth during unfavorable periods, such as poor availability of food caused by various factors like low temperature or maturation of gonads.

Annulus formation has been attributed to various factors such as variation in temperature (Johal and Tandon, 1987; Johal *et al.*,1987; Tandon and Johal, 1983; Johal *et al.*,1984; Tandon *et al.*,1989a; Tandon *et al.*,1989b; Carlender, 1943; Holcik, 1967;); spawning (Johal and Tandon, 1981; Johal and Tandon, 1983; Johal and Tandon, 1987; Johal *et al.*,1987; Tandon and Johal, 1983; Tandon *et al.*,1989a; Tandon *et al.*,1989b; Natrajan and Jhingran, 1963; Hanumantharao, 1974; Rammohana, 1974); feeding intensity (Johal and Tandon, 1981; Johal and Tandon, 1983; Johal and Tandon, 1987; Johal *et al.*,1987; Tandon and Johal, 1983; Tandon *et al.*,1989a; Tandon *et al.*,1989b;

Natrajan and Jhingran, 1963; Hanumantharao, 1974; Rammohana, 1974) and migration and changes in salinity (Fagade, 1974)

It has been further observed that in northern India these factors are influenced by south - west monsoon and is responsible for the formation of annual mark (Johal and Tandon, 1981; Johal and Tandon, 1983; Johal *et al.*,1987; Tandon and Johal, 1983; Johal *et al.*,1984; Tandon *et al.*,1989; Jhingran, 1959; Jhingran, 1968; Natrajan and Jhingran, 1963; Kamal, 1969; Khan and Siddiqui, 1973; Khan and Jhingran, 1975; Jhingran and Khan, 1979, Pathani, 1981; Johal *et al.*,1989; Hanumantharao, 1974; Rammohana, 1974). If these factors fail to take place, the formation of an annulus is skipped or delayed.

Kesteven (1942) while discussing the causative factors in the formation of 'breaks' in *Mugil dobula*, stated that feeding had ceased for a period during which resorption may have occurred causing annulus formation. Royce (1972) described that some fishes stop feeding completely during spawning and growth rate of the fish is affected. Bisht *et al.*,(1996) reported that in *Schizothorax plagiostomus*, spawning may be the main causative factor for the periodic structure of wider (fast growing) and narrower (slow growing) zones. Blackburn (1949) in Australian Pichard, Chako and Krishnamoorty (1950) in hilsa, Seshappa (1958) in Mackerel, Natrajan and Jhingran (1963) in *Catla catla* and Dobriyal and Singh (1990) in *Arilius bendelisis* have considered these rings as spawning marks. Hecht (1980) observed that in sexually immature fish the breeding ring is also deposited which suggests the ring deposition is inherently linked to the reproductive cycle. Chako *et al.*,(1950), in their studies on *Hilsa ilisha* of the Godavari, clarified the significance of the growth rings on scale. According to them, there is a period of starvation concurrent with the spawning act and during the period there is a

general adsorption of all the tissues of body, the scales also being affected by the formation of a ring. Pantulu (1961, 1962, 1963) while studying the age and growth of catfishes *Mystus gulio, Pangasius pangasius* and *Osteogeniosus militaris*, mentioned that high temperature in tropics associated with poor availability of food and physiological stress created by the development of gonadal material and subsequent spawning are the causative factors for annulus formation.

In the present study, the period of annulus formation (July - August) corresponds with gonad maturation and spawning of *Puntius sophore*. This period also corresponded with the low feeding activity of the fish. Hence, it is quite probable that these factors might have played a significant role for the formation of annulus in this species also.

According to Chugunova (1963) and Balon (1971 a, b), the index of population weight growth intensity (ΦCw) and specific rate of linear growth (C_l) could be used to compare the growth rates of fishes. Commercial importance of the fish could be considered by the use of index of species average size(Φh). The study of growth parameters is thus helpful in understanding the complex phenomenon of growth. Chitravadivelu (1972), Balon (1974), Singh (1978), Johal and Tandon (1981, 1985, 1987), tandon and Johal (1983) and Tandon *et al.*,(1989 a, b) have used these parameters in some freshwater fishes yielding good results. The growth parameters of Puntius sophore are given in Table 8.3.

The specific rate of linear growth (C_l) decreased with the increase in age in this species. The absolute weight increase (w) showed increasing trend with the increase in age. On the contrary, the values of specific rate of weight increase (Cw), decreased with the increase in age. The value of index of population weight growth intensity (fCw) is

3.5. The value of index of species average size (fh) has been found to be 23 mm. In the present study, the growth constant data have indicated that there are two periods in the life of *Puntius sophore*. The average growth constant of first and second periods are 0.4 and 0.25 respectively. On the basis of values of growth constant and average growth constant (Av. C_{lt}) it is observed that, the fish has very short inactive sexual phase, i.e., up to the end of second year of life. Then it enters the active sexual phase but never enters 'old age'.

Age of fish was determined by the scale was confirmed by the length frequency analysis (Fig. 6.3). In the present study the clumping in population was observed at 52 mm, 67 mm, 81 mm, and 92 mm which showed this length to be in the first, second, third and fourth year respectively. According to Lagler (1977), the length frequency method is based on the expectancy that the frequency analysis of a species of any one age group collected on the same date will show variations around the mean length according to normal distribution, it is based further on the expectations that when data for a sample of entire population are plotted, there will be clumping of fish of successive age about successive given lengths, making possible a separation of age groups.

The theoretical harvestable size was determined from the crossing points of the following curves (a) length increment in percentage of length of the first growth season and (b) length (at ages) in percentage of length of the final growth season. The percentage were plotted on the Y-axis and age classes on the X-axis. This method has been adopted for other commercial freshwater fishes also (Chitravadivelu, 1972; Holcik, 1974; Tandon and Oliva, 1977; Johal and Tandon 1987 a, b; Tandon and Johal, 1996). The harvestable size of this fish was found to lie between the age classes 1-2 when the

total lengths varies between 48 - 64 mm (Fig. 6.4). It almost lies in between the active sexual phase determined from the value of average growth constant. This observation confirms the observation on the average growth constant (Table 6.3) also as at the minimum harvestable size the population enters the second period, i.e., active sexual period. In general, the minimum harvestable size should be coincide with the beginning of the sexual maturity.

In the present study the age at first maturity of *Puntius sophore* was determined by plotting the size at first maturity with age in years (Fig. 6.5) It was observed more than one year for male fishes and more than two year for female fishes. There are reports of maturity in fishes in the first year (Hora and Pillay, 1962), second year (Alikunhi, 1957; Khan and Jhingran, 1975) and third year of life (Khan, 1972).

Table 6.1: Percentage occurrence of scales with minimum width in Terminal Zone during different months.

Months	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Total no. of fish examined	33	35	45	50	41	47	70	62	48	28	28	25
Number of fish possessing minimum width in terminal Zone	-	-	-	-	8	24	65	62	21	5	-	-
Percentage of fish possessing minimum width in terminal Zone	-	-	-	-	19.5%	51.06%	92.8%	100%	43.75%	17.8%	-	-

Table 6.2: Back – calculated length (mm) of *Puntius sophore* (Ham.)

Age class	*Number of Specimens*	*Total length (mm) Average*	*Length of fish (mm) at the time of annulus formation*			
			l_1	l_2	l_3	l_4
1	89	54 (45-62)	47 (42-54)			
2	196	69 (51-79)	47 (31-63)	60 (41-75)		
3	112	80 (65-90)	44 (39-68)	63 (54-78)	74 (62-85)	
4	115	98 (81-116)	55 (44-73)	70 (53-85)	85 (72-97)	95 (77-110)
Total/ Average	512	75 (45-116)	48 (42-73)	64 (41-85)	79 (62-97)	95 (77-110)

Table 6.3 : Summary of growth data on *Puntius sophore*

Growth parameter	*Years of life*						
	1		2		3		4
L (mm)	48		64		79		95
h (mm)	48		16		15		16
Φ h (mm)				23			
C_l		33		23		20	
C_{th}		13.1		13.5		14.5	
C_{lt}		0.4		0.3		0.2	
Av. $_{clt}$		0.4			0.25		
W (gm)	1.9		4.2		7.3		12.0
W (gm)	1.9		2.3		3.1		4.6
Cw		21		34		48	
Φ Cw (gm)				3.5			

Fig.6.1 : Fish length- scale radius relationship in *P. sophore*

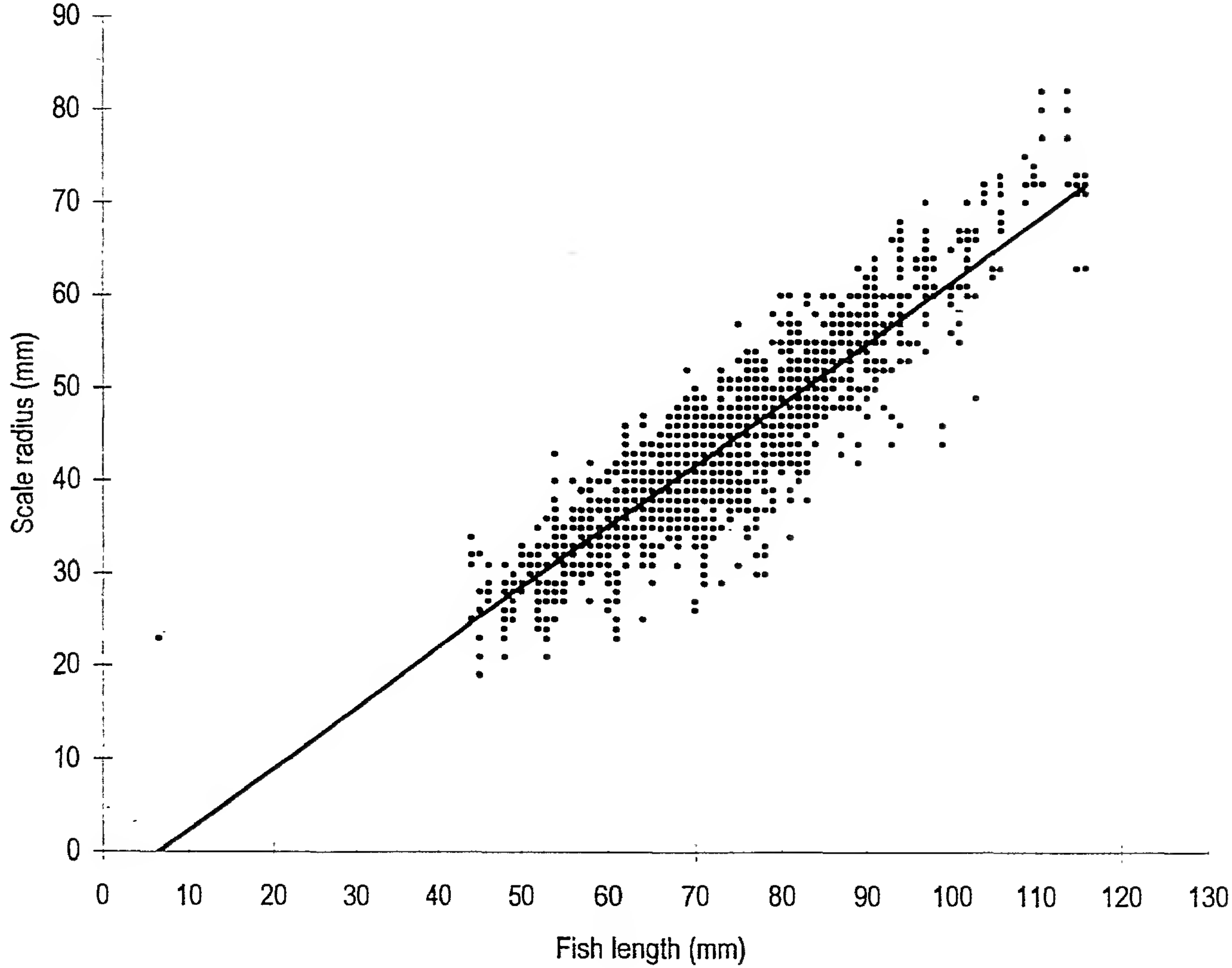
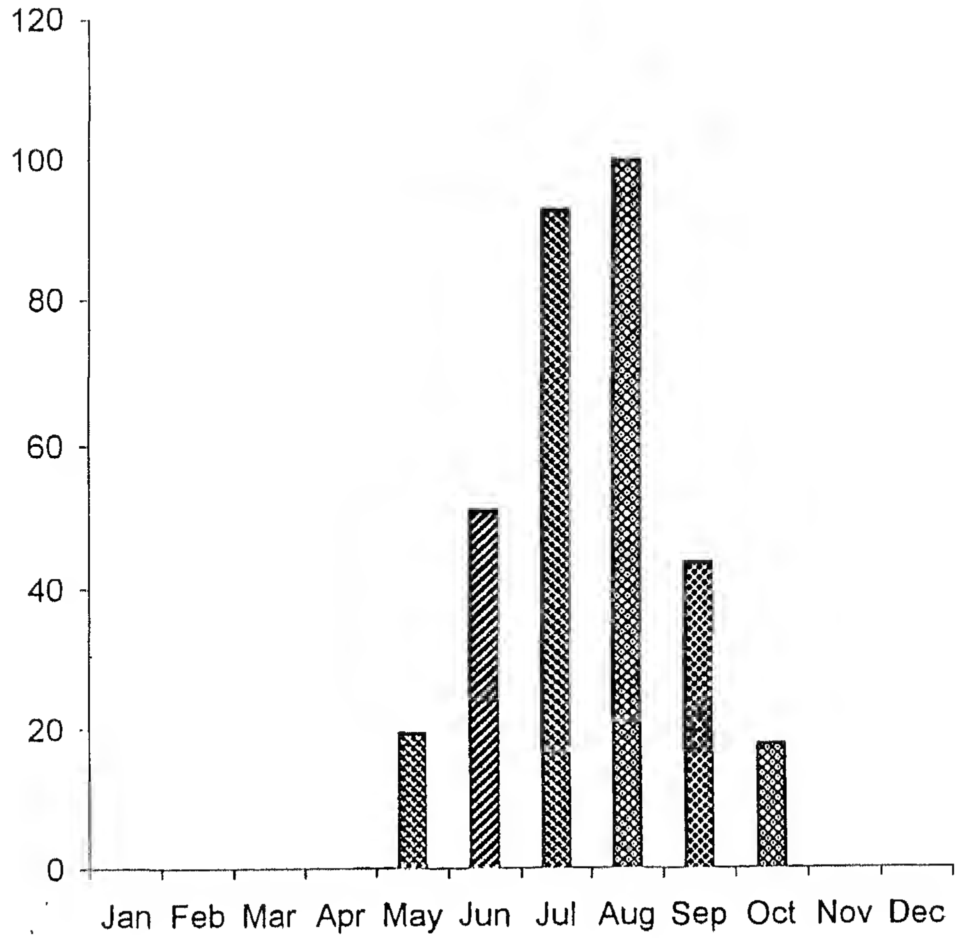


Fig 6.2: Percentage occurance of scales with minimam width in terminal zone during different months



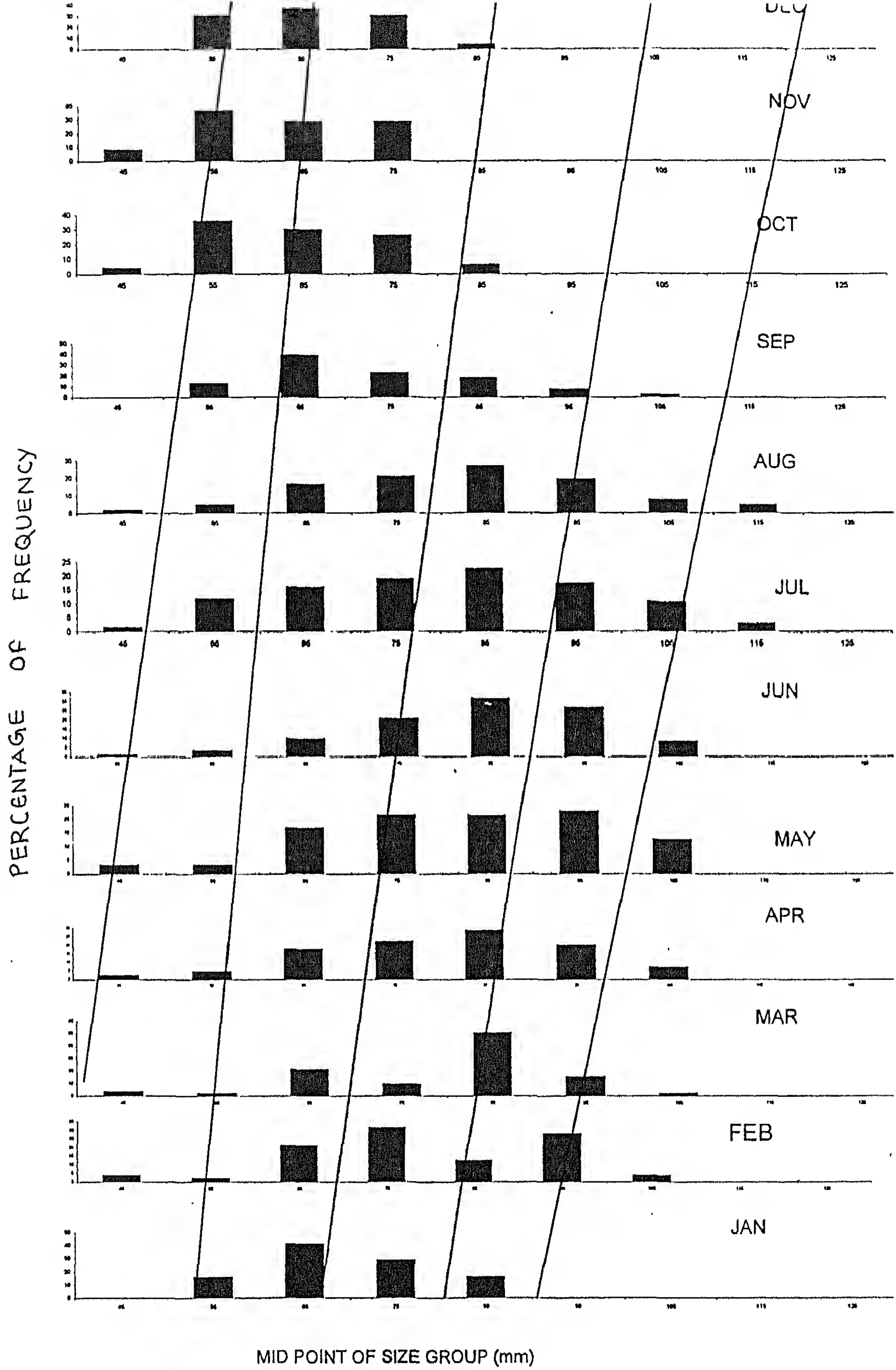


Fig.: 6·3 Length Frequency Distribution of P.sophore

Fig 6.4: Harvestable size of *Puntius sophore*

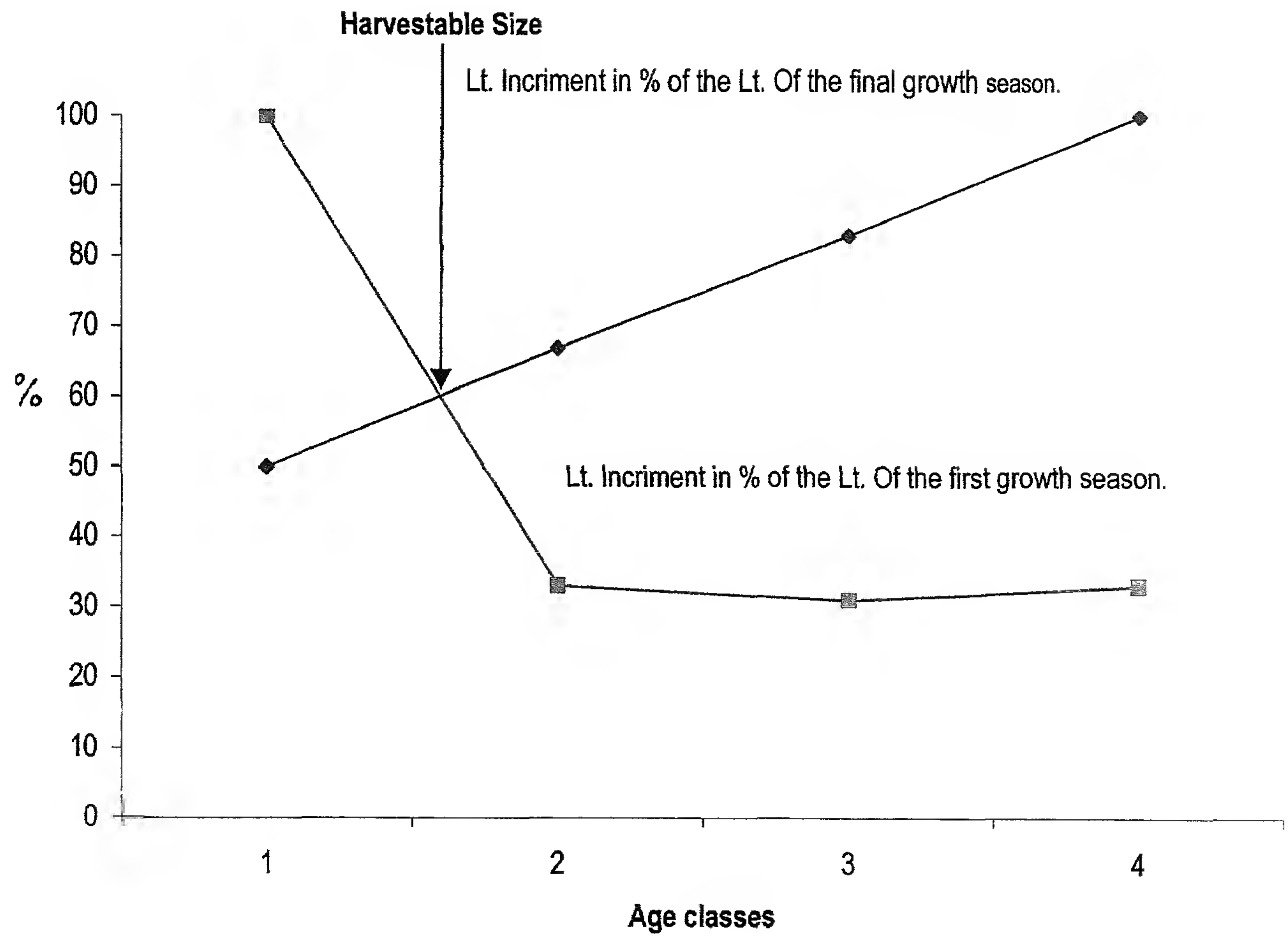
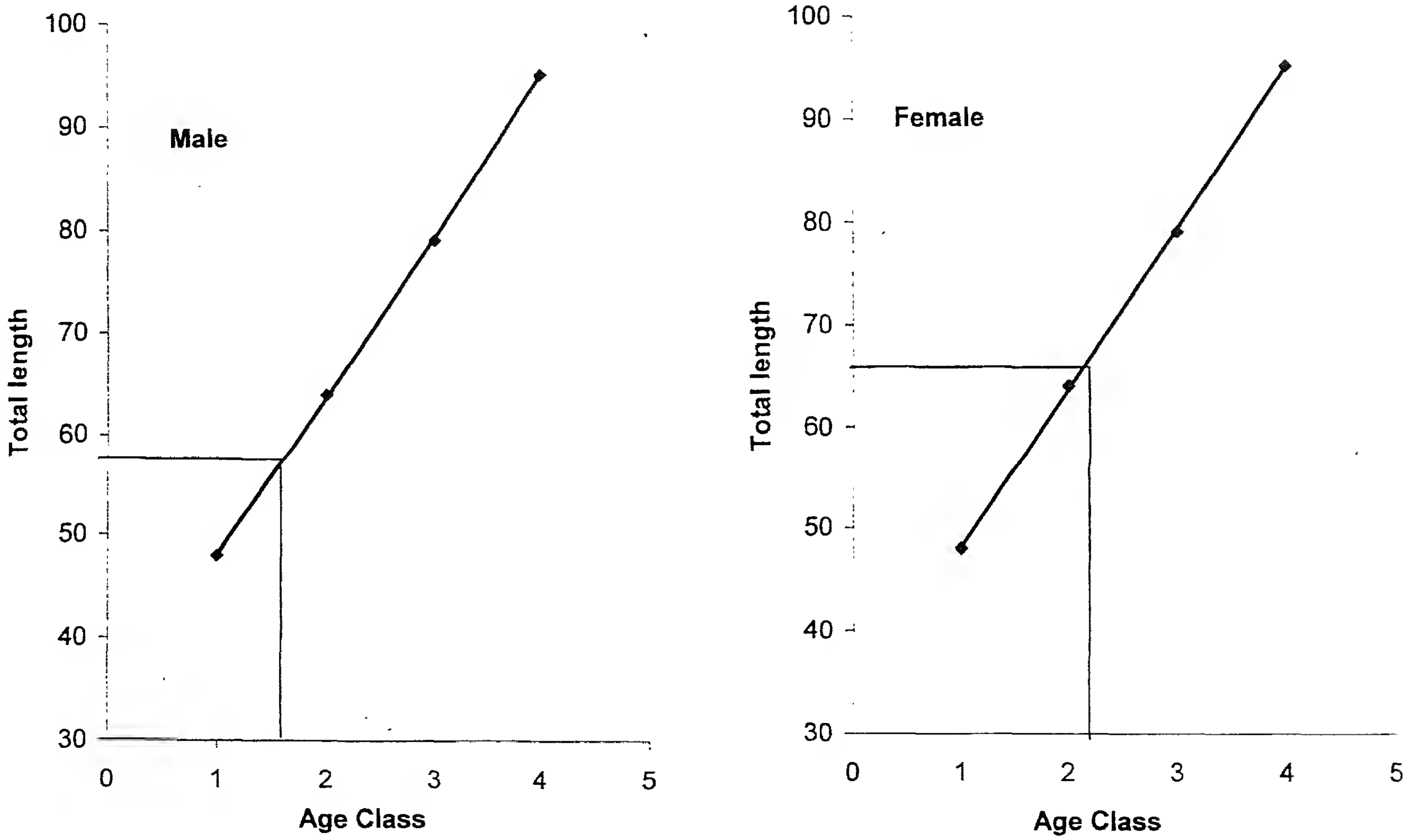
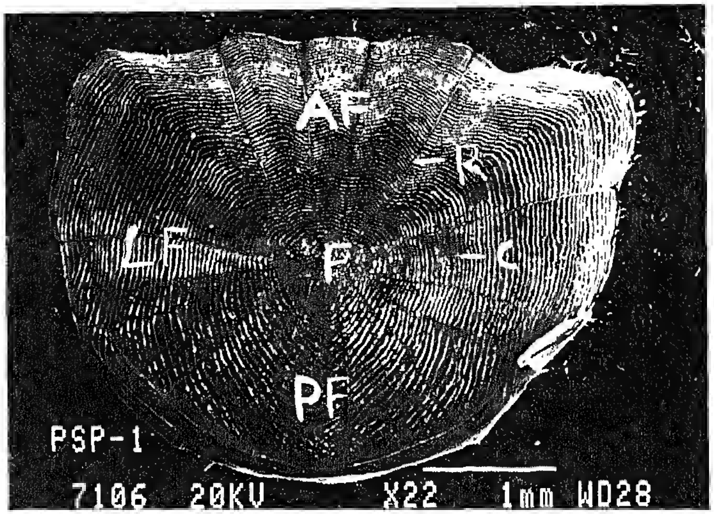
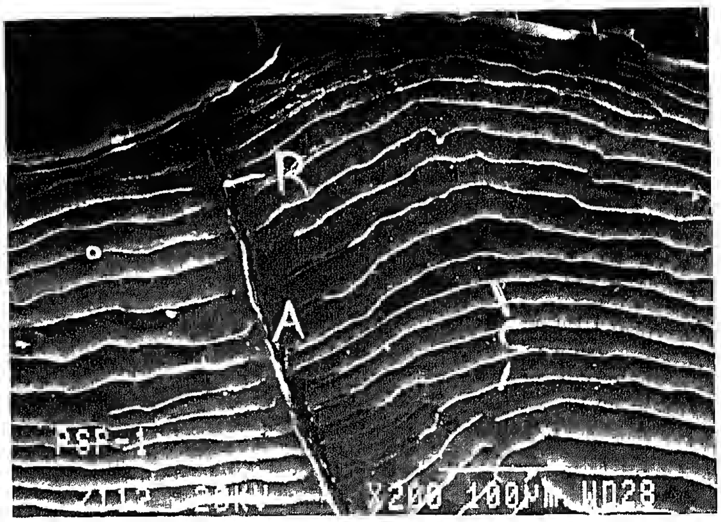


Fig 6.5: Age at first maturity of Puntius sophore

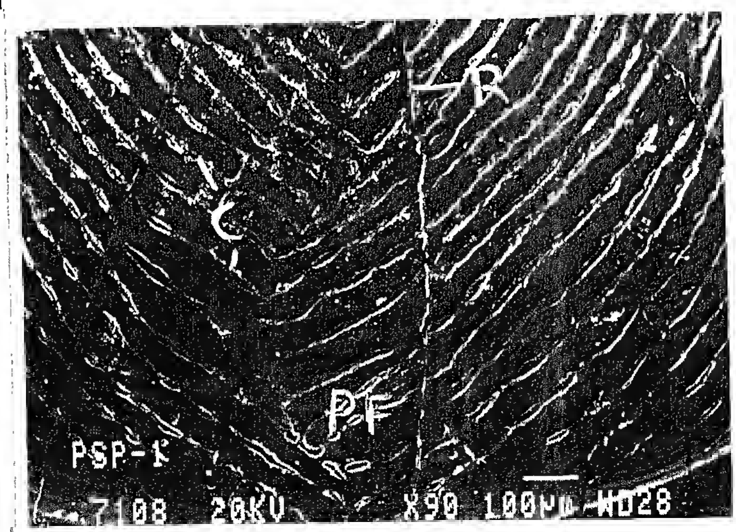



AF
R
LF
F
C
PF
PSP-1
7106 20KV X22 1mm WD28

5.1


R
A
PSP-1
X200 100µm WD28

5.2

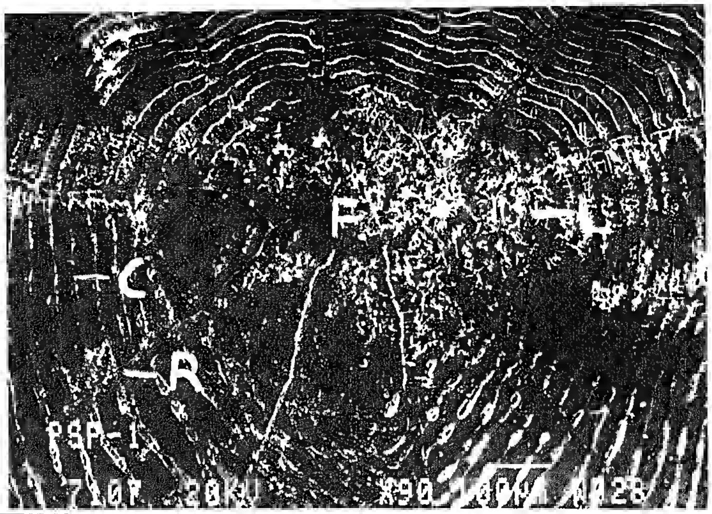

R
C
PF
PSP-1
7108 20KV X90 100µm WD28

5.3

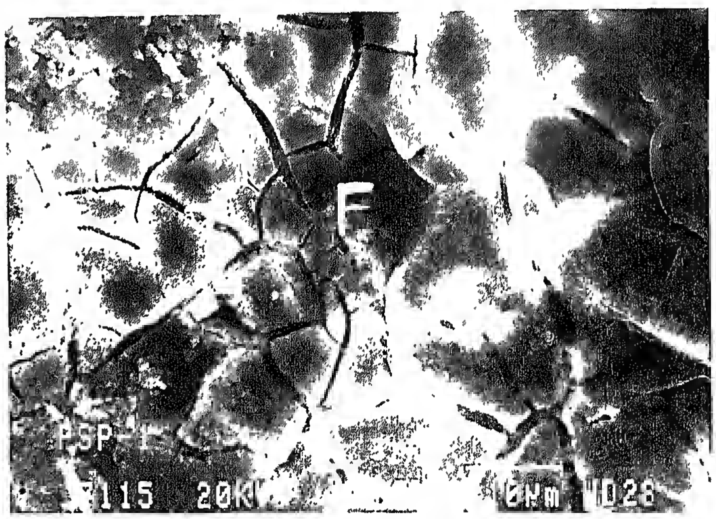
Fig 5.4: SEM photomicrograph of scale of *Puntius sophore* showing focus (F).

Fig 5.5: SEM photo micrograph of scale *Puntius sophore* showing details of the focus (F).

Fig 5.6: SEM photomicrograph showing chromatophore (Ch) on the posterior field (PF) scale of *Puntius sophore*.


F
C
R
PSP-1
20KV
X90
WD28

5.4


F
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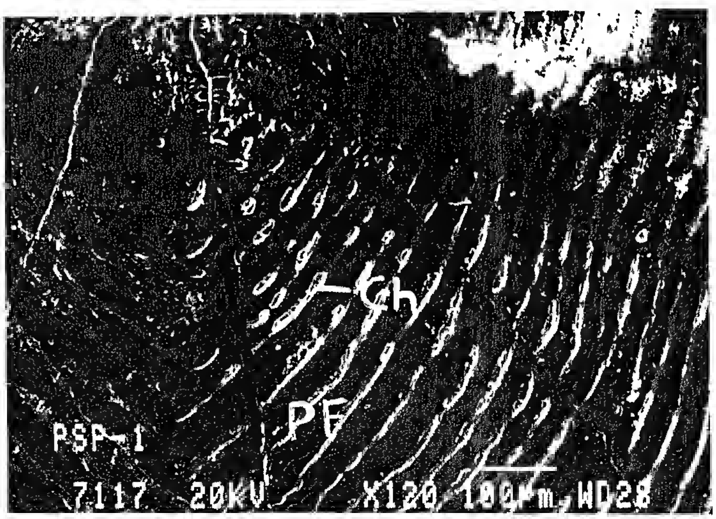
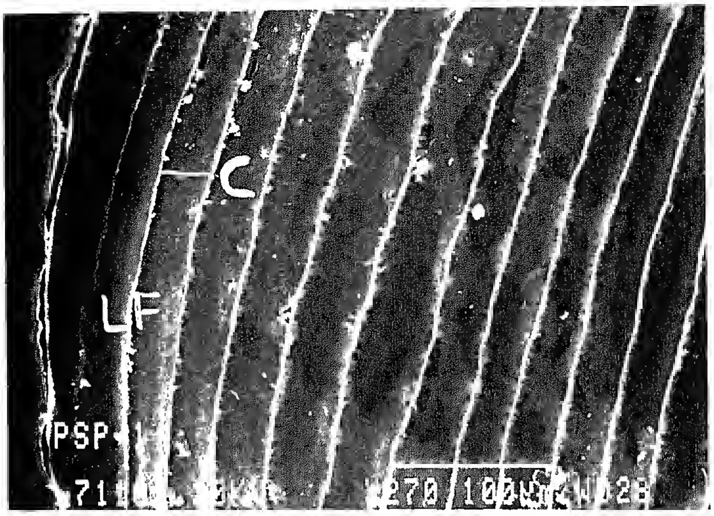
7115 20KV
WD28

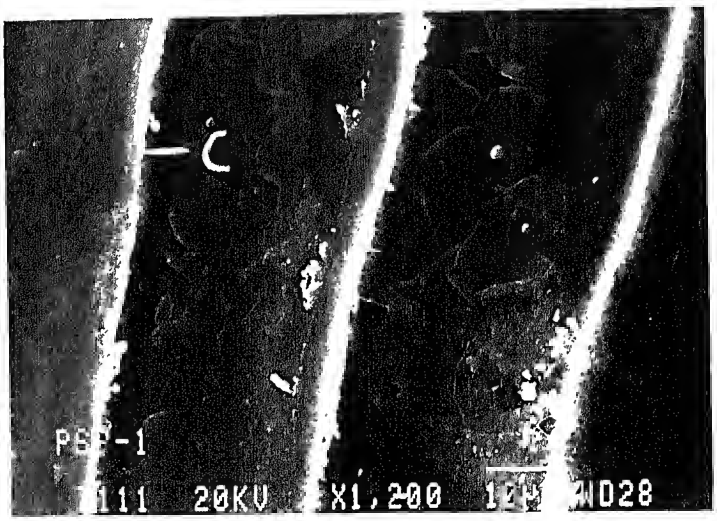
5.5


Ch
PF
PSP-1
7117 20KV X120 100µm WD28

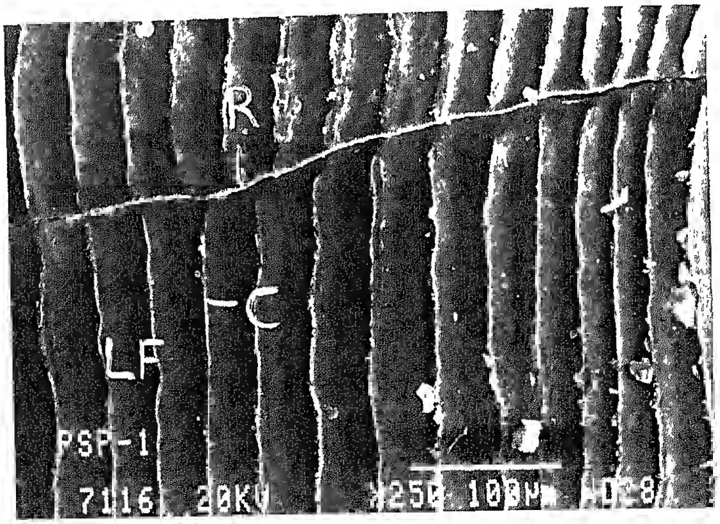
5.6



5.7



5.8



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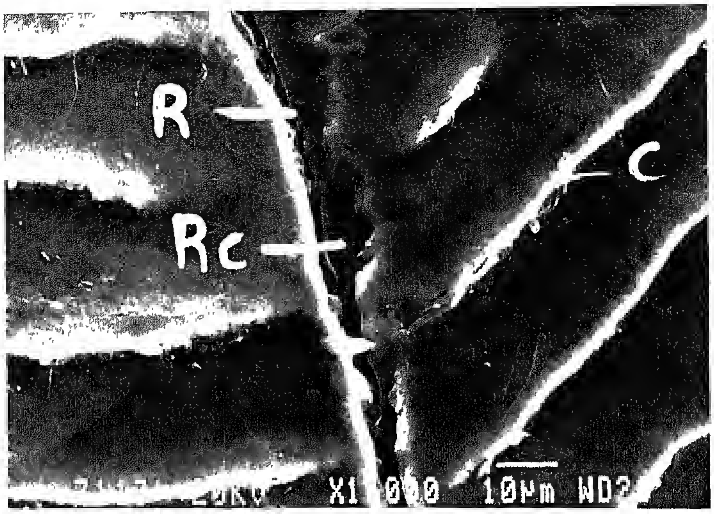
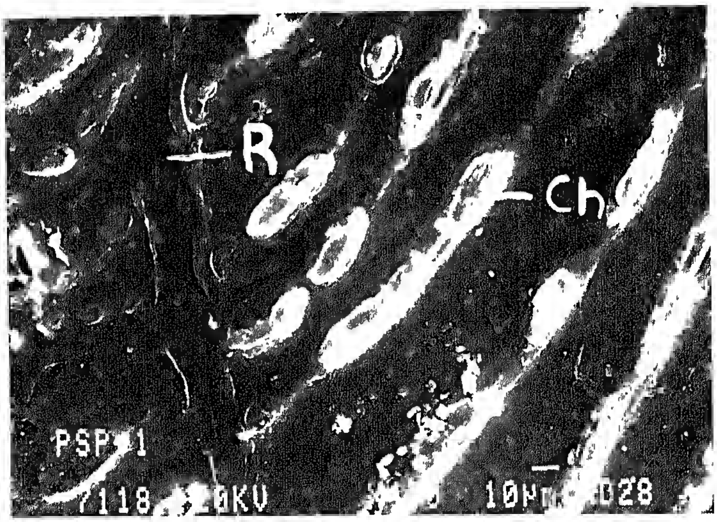
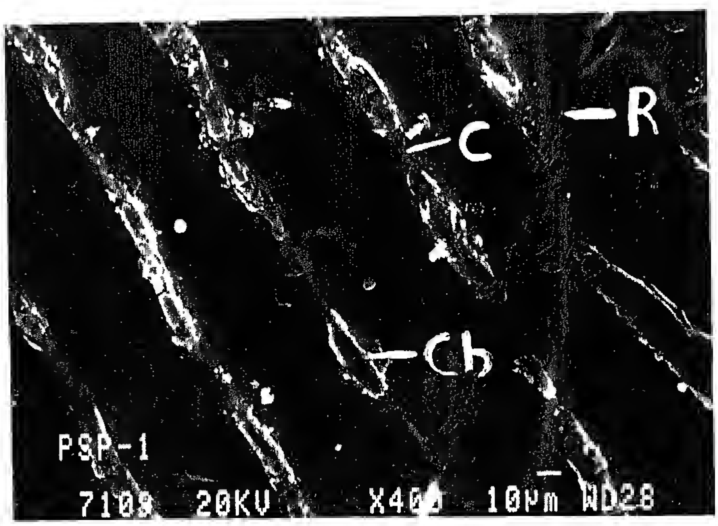

R
Rc
C
10Pm

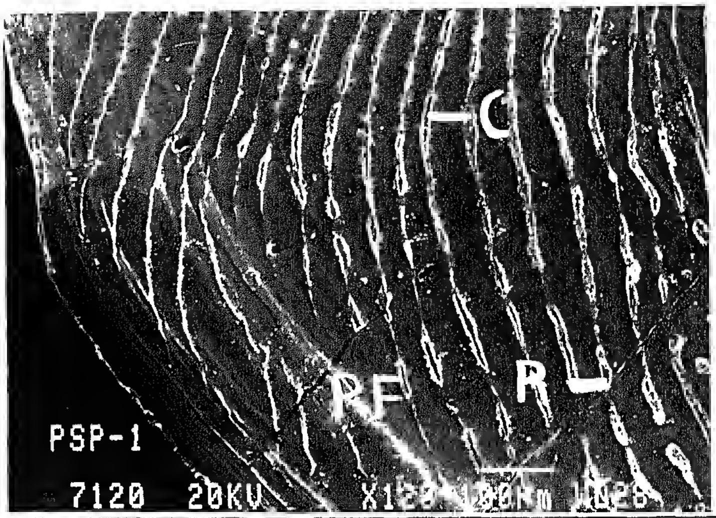
5.10


R
Ch
PSP-1
7118 20KV
10Pm WD28

5.11


C
R
Ch
PSP-1
7109 20KV X400 10Pm WD28

5.12



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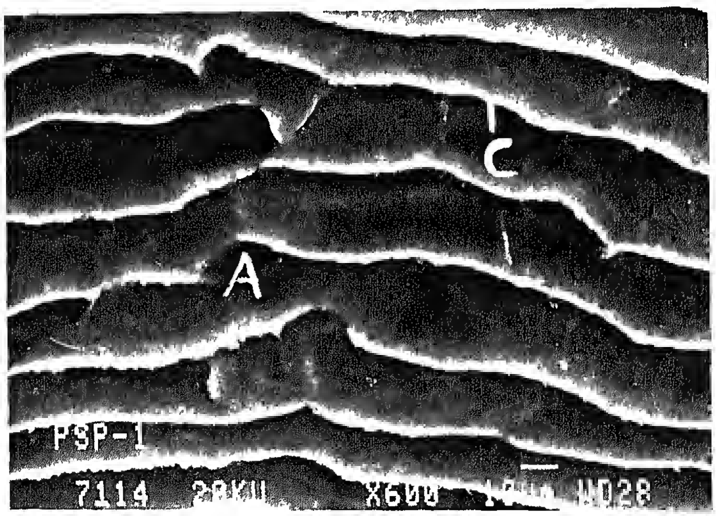

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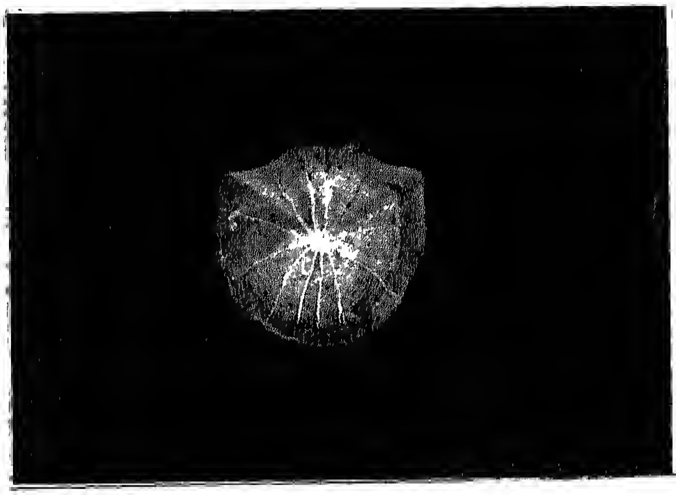

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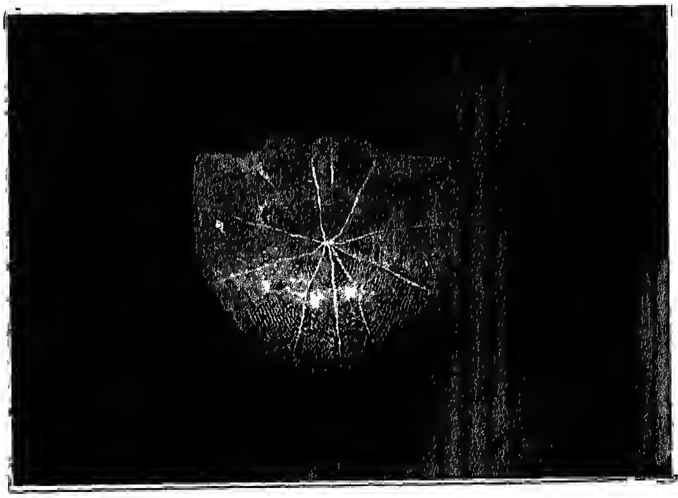

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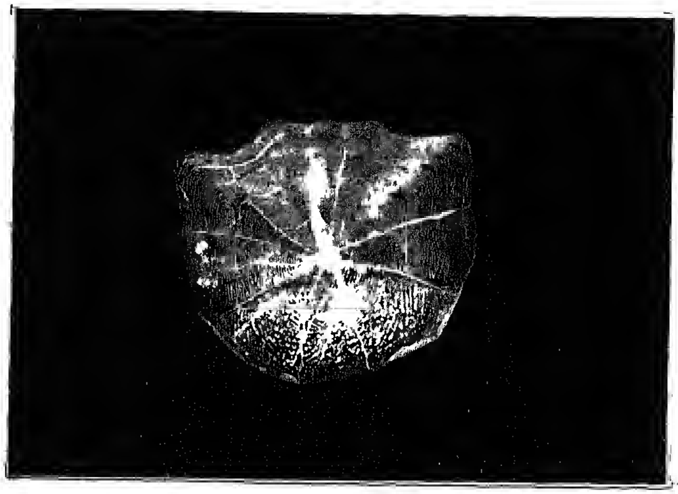
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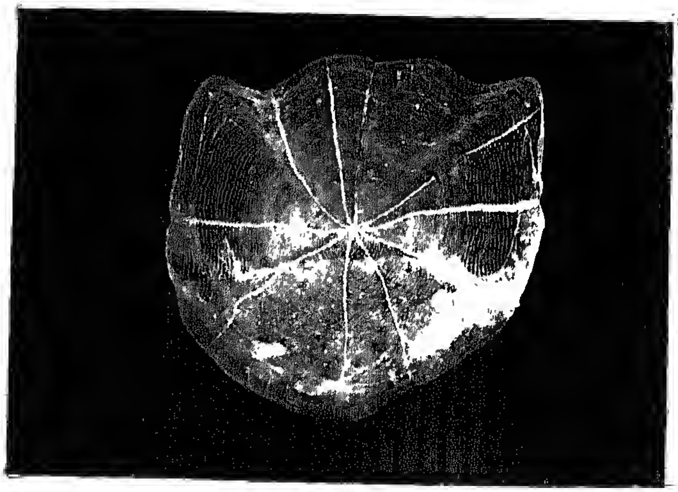
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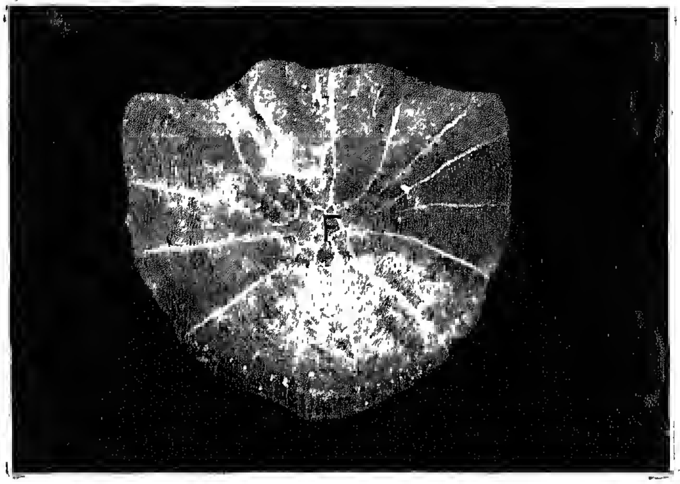

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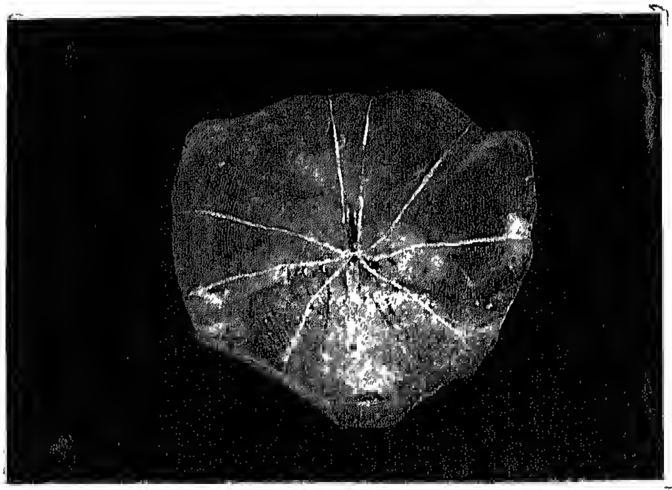

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CHAPTER VIII

SUMMARY

SUMMARY

The present study was carried out on some aspects of fishery biology of *Puntius sophore* (Ham.) from the Ganga river system at Allahabad. For this study regular weekly collections were made during January 2001 to December 2002. Important aspects of fishery biology such as morphometrics, length-weight relationship, food and feeding habit, breeding biology and age and growth were studied. The main observations are summarized as follows :

I. Morphometrics

Eleven morphometric parameters were studied to established the relationship between them. These parameters are : total length, standard length, head length, snout length, eye diameter, postorbital length, predorsal length, prepelvic length, preanal length, maximum body depth and caudal length. They were studied in relation to the total length and standard length of fish. Snout length, eye diameter and postorbital length were also studied in relation to head length. The percentage between dependent variables and independent variables were found in decreasing order, whereas the ratio was in increasing order. The regression equation and correlation coefficient (r) for all the relationships were determined by using the straight line equation,

$$Y = a + b X$$

Where X = independent variable, Y = dependent variable, a = intercept, and b= slope of the regression line.

The value of correlation coefficient (r) was calculated in each case to know the degree of relationship between the independent and dependent variables and in all cases the value of correlation coefficient (r) was recorded quite high (0.8088 to 0.9937), indicating a high degree of correlation in growth between the body parameters i.e., independent and dependent variables. The standard length was found the most correlated body parameter with the total length (r = 0.9937) and lowest correlation was recorded between the standard length and postorbital length (r = 0.8088). The values of correlation coefficient (r) were tested by applying 't' test and it was found that all the values are significant. The linearity of regression was proved by analysis of variance (ANOVA).

The samples of *Puntius sophore* collected from Ganga river system belong to a homogeneous population. Various body parts grow in accordance to the total length of fish and showed a high degree of correlation with total length and standard length and lowest correlation between standard length and postorbital length.

2. Length-weight relationship

Length-weight relationship equation was observed for different sexes, for different seasons and for pooled data. The value of regression coefficient 'b' was found always below 3, (1.8988 to 2.9522). It reflects the fact that the weight of this species increases slightly less than the cube of its length. This shows the departure of this fish from isometry (b=3). In *Puntius sophore*, the 'b' value was found maximum (2.9522) for females during monsoon and minimum (1.8988) for males during summer, which indicated that the growth of fish was slightly more during monsoon and less during summer. The high value of exponent 'b' during monsoon indicates the breeding season of this fish. The value of correlation coefficient (r) was high between length and weight

of *Puntius sophore* and it varies from 0.77244 to 0.95306. Analysis of variance (ANOVA; 'F' test) revealed that per millimeter increase in the total length was significant for per gram gain in weight of fish. The 'F' test shows that the values of 'F' for all the relationships are significant. Significance of regression coefficient 'b' was also tested by applying 't' test and it was observed that all the values are significant at 0.05% level.

The relative condition factor (Kn) was recorded high during monsoon season in the month of July and might be due to great increase of gonads which sharply declined after spawning in October. The Kn value in the smallest size group may be attributed to high feeding.

3. Food and feeding habits

The food items of *Puntius sophore* were studied qualitatively and quantitatively. The main food items found in the gut contents are semi-digested unidentified green matter, algae, diatoms, parts of insects and their larvae, crustaceans and their larvae, rotifers and other miscellaneous items such as parts of leaves of macrophytes, sand-mud, debris and detritus. Semi-digested unidentified green matter was found to be the most dominant food item. The fish is omnivorous and euryphagic. The percentage of plant and animal food during winter, summer and monsoon season was 86.9 / 13.1, 64.3 / 38.7, 36.5 / 63.5 respectively, the annual average was 62.5 and 37.5 respectively. This fish consumes more plant matter than animal matter, hence it may be called as herbi-omnivore. The more consumption of animal matter during monsoon could be attributed to non-availability of plant food during monsoon months. Since the availability of food items varies in nature, the fish feeds on the available food items only. During winter and summer the basic food of this fish is green matter and algae, while during monsoon the

basic food consists of insects and their larvae and crustaceans and their larvae. Diatoms were found in the gut contents throughout the year and formed the secondary food. Rotifers were considered as incidental food. Miscellaneous food items might be considered as obligatory food. The negligible percentage of sand-mud, debris and detritus and shape of mouth (terminal) show a column feeding tendency.

The Gastrosomatic index (GaSI) was recorded maximum in January and minimum during July - August, which was due to heavy growth of gonads and non-availability of food due to flood. Relative length of gut (RLG) values ranged from 1.72 to 3.02, depending upon the size of fish and availability of food items. The highest feeding index (FI) was observed during winter with a peak in January, which decreased in prespawning and spawning months due to the development of gonads.

Puntius sophore (Ham.) inhabiting the Ganga river system at Allahabad is herbi-omnivore, column feeder and euryphagus in nature. Its feeding intensity was recorded maximum during winter months and quite low during breeding season.

4. Breeding biology

Based on the ova diameter measurements and their frequency polygon, six maturity stages were recognised. These are immature, maturing I, maturing II, mature I, mature II and spent. The maximum value of Gonadosomatic index (GSI) was calculated 1.849 for male and 12.075 for female in the month of July. Progression of the size frequency distribution of ova and GSI indicated that the fish spawned only once in a year during August - September. The 50% level in the maturity which has been taken to represent the mean length at which the maturity was obtained was 58 mm and 66 mm for male and female *Puntius sophore* respectively. This shows that the fish matures earlier than female.

Fecundity of *Puntius sophore* ranged from 439 to 24385 in the fishes having a length range of 52 to 116 mm. A linear relationship between the fecundity and body parameters like fish length, fish weight, ovary length and ovary weight was obtained. Fecundity was more closely related to the ovary weight (r= 0.95479) and fish length (r = 0.91047) than the fish weight (r = 0.88959) and ovary length (0.73668). The analysis of variance (F-test) was significant for all the relationships. This indicates that fecundity depends on the fish length and weight and ovary length and weight. The relative fecundity (number of eggs per gram body weight) was found in increasing order with the increase of fish weight and ovary weight.

The sex ratio (male : female) was studied. For this a total number of 605 specimens were examined, out of which 211 (34.9%) were males and 394 (65.1%) were females. The mean ratio was observed to be 1:1.86 between males and females. The Chi-square analysis reveals that most of the values are significant, that means the variation in the sex ratio from natural one (1:1) is more.

5. *Age and growth*

The age and growth of *Puntius sophore* was studied by the annulus method using key scales and by length-frequency distribution . A linear relationship with high degree of correlation was observed between total lengths and scale radii of fish. The relationship is expressed as follows :

$$SR = -4.4696 + 0.6613\ FL \quad (r = 0.8863)$$

Where, FL = total length of fish, SR = scale radius, and r = correlation coefficient

The scale appeared for the first time on the body when fish had attained a length of 8 mm. This value has been considered as correction factor. The highest percentage

frequency of minimum width in the terminal zone of scale was recorded during July and August, suggesting their formation in these months. As this type of condition was not observed in other months, it might be assumed that the formation of growth ring was annual in nature. The spawning and low feeding stress were the causative factors for annulus formation.

Fishes under examination belonged to 0 to 4 age classes. The maximum number of specimens were recorded for age class 2. The mean back calculated lengths (in mm) obtained by the analysis of pooled key scale samples were 48, 64, 79 and 95 for the first to four age classes respectively. The annual length increment (in mm) was recorded 48, 16, 15 and 16 for one to four age classes respectively. Specific rate of linear growth was observed to be 33 between first and second year, 23 between second and third year and 20 between third and fourth year.

Index of species average size i.e., average increase in length was observed 23. The value of growth characteristic was recorded (13.1) during first and second year which increased in second and third year (13.5) and third and fourth year (14.5). The maximum growth was observed between third and fourth year of life. The growth constant shows two phases of life, upto one year immature and two to four years mature phase. This shows that *Puntius sophore* do not enter old age. Phenomenon of growth compensation was not observed in this fish.

Age of fish determined by the scale was confirmed by the length – frequency distribution analysis. The clumping in population was recorded at 52 mm, 67 mm, 81 mm and 92 mm which showed that this length to be in first, second, third and fourth year respectively. The harvestable size was calculated 62.0 mm for this fish, which the fish

attains in about 1 year and 10 months. The age at first maturity was found below two years for male and above two years for female fishes.

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